Canada Alberta Northwest Territories

Northern River Basins Study



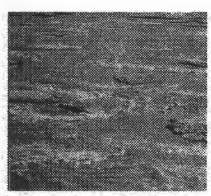


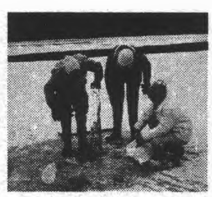





NORTHERN RIVER BASINS STUDY PROJECT REPORT NO. 128

DESIGN AND APPLICATION OF A TRANSPORTABLE EXPERIMENTAL STREAM SYSTEM FOR ASSESSING EFFLUENT IMPACTS ON RIVERINE BIOTA







DATE DUE

Prepared for the
Northern River Basins Study
under Project 2611-C1

by

Joseph M. Culp, Cheryl L. Podemski and Carol Casey
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Published by the
Northern River Basins Study
Edmonton, Alberta
February, 1996

CANADIAN CATALOGUING IN PUBLICATION DATA

Culp, Joseph M.

Design and application of a transportable experimental
stream system for assessing effluent impacts on
riverine biota

(Northern River Basins Study project report,
ISSN 1192-3571 ; no. 128)
Includes bibliographical references.
ISBN 0-662-24488-5
Cat. no. R71-49/3-128E

1. Aquatic organism -- Effect of water pollution on --
Alberta -- Athabasca River -- Measurement.
2. Wood pulp industry -- Waste disposal -- Environmental
aspects -- Alberta -- Athabasca River -- Measurement.
I. Podemski, Cheryl L.
II. Casey, Carol.
III. Northern River Basins Study (Canada)
IV. Title.
V. Series.

TD899.W65C84 1996 574.5'26323 C96-980171-8

PREFACE:

The Northern River Basins Study was initiated through the "Canada-Alberta-Northwest Territories Agreement Respecting the Peace-Athabasca-Slave River Basin Study, Phase II - Technical Studies" which was signed September 27, 1991. The purpose of the Study is to understand and characterize the cumulative effects of development on the water and aquatic environment of the Study Area by coordinating with existing programs and undertaking appropriate new technical studies.

This publication reports the method and findings of particular work conducted as part of the Northern River Basins Study. As such, the work was governed by a specific terms of reference and is expected to contribute information about the Study Area within the context of the overall study as described by the Study Final Report. This report has been reviewed by the Study Science Advisory Committee in regards to scientific content and has been approved by the Study Board of Directors for public release.

It is explicit in the objectives of the Study to report the results of technical work regularly to the public. This objective is served by distributing project reports to an extensive network of libraries, agencies, organizations and interested individuals and by granting universal permission to reproduce the material.

NORTHERN RIVER BASINS STUDY
PROJECT REPORT RELEASE FORM

This publication may be cited as:

Culp, Joseph M., Podemski, Cheryl L. and Casey, Carol. 1996. *Northern River Basins Study Project Report No. 128, Design and Application of Transportable Experimental Stream System for Assessing Effluent Impacts on Riverine Biota.* Northern River Basins Study, Edmonton, Alberta.

Whereas the above publication is the result of a project conducted under the Northern River Basins Study and the terms of reference for that project are deemed to be fulfilled,
IT IS THEREFORE REQUESTED BY THE STUDY OFFICE THAT;
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(Dr. Fred J. Wrona, Science Director) — 4 Apr 96 (Date)

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IT IS HERE ADVISED BY THE SCIENCE ADVISORY COMMITTEE THAT;
this publication has been reviewed for scientific content and that the scientific practices represented in the report are acceptable given the specific purposes of the project and subject to the field conditions encountered.
SUPPLEMENTAL COMMENTARY HAS BEEN ADDED TO THIS PUBLICATION: [ ] Yes [ ] No

(Dr. P. A. Larkin, Ph.D., Chair) — April 15/96 (Date)

Whereas the Study Board is satisfied that this publication has been reviewed for scientific content and for immediate health implications,
IT IS HERE APPROVED BY THE BOARD OF DIRECTORS THAT;
this publication be released to the public, and that this publication be designated for: **[ ] STANDARD AVAILABILITY [ ] EXPANDED AVAILABILITY**

(Lucille Partington, Co-chair) — 21 April 1996 (Date)

(Robert McLeod, Co-chair) — 10 April 1996 (Date)

DESIGN AND APPLICATION OF A TRANSPORTABLE EXPERIMENTAL STREAM SYSTEM FOR ASSESSING EFFLUENT IMPACTS ON RIVERINE BIOTA

STUDY PERSPECTIVE

An important initiative of the Northern River Basins Study is the development of methods for assessing the effects of industrial effluents on the health and integrity of the aquatic ecosystem. These effluents contain a wide array of compounds, and their effects can be stimulatory (in the case of nutrients) or inhibitory (in the case of some natural tree compounds). High levels of nutrients contained in pulp mill effluents can result in significant changes in the primary productivity of some rivers, but these enhancement effects can mask the toxic effects of contaminants on riverine biota. Because of the complex interaction between effluent compounds and the receiving environment, difficulties arise when biomonitoring studies attempt to predict accurately the impacts of effluents on the aquatic food chain. This study discusses the design of an innovative artificial stream system for the purpose of assessing the combined effects of nutrients and contaminants in effluent discharges on riverine food chains.

Related Study Questions

1a) *How has the aquatic ecosystem, including fish and /or other aquatic organisms been affected by exposure to organochlorines or other toxic compounds?*

4a) *What are the contents and nature of the contaminants entering the system and what is their distribution and toxicity in the aquatic ecosystem with particular reference to water, sediments and biota?*

5 *Are the substances added to the river by natural and man-made discharges likely to cause deterioration of the water quality?*

13b) *What are the cumulative effects of man-made discharges on the water and aquatic environment?*

The objective of this project was to design and construct a transportable artificial stream for testing impacts of nutrients and contaminants from pulp mill effluents on aquatic ecosystems in rivers. This report describes the design of that artificial system, and its placement beside the Athabasca River at Hinton. The description also includes specific hydraulic characteristics, important details and procedures of installation, and results from initial start-up tests of the system.

The artificial stream system described here will be used in subsequent NRBS experiments to address the effects of nutrients, contaminants and their interaction on benthic invertebrates and algal productivity in the Athabasca River near Hinton. This information is important for assessing the immediate and long-term effects of pulp mill effluents on biota, and for preserving aquatic habitats in these northern river systems. Results from these experiments will form an important linkage with other NRBS studies dealing with food chain and contaminant fate modelling, and assessing ecosystem health in these rivers.

REPORT SUMMARY

In the Northern Rivers Basin Study artificial streams were used to investigate effects of treated pulp mill effluents and nutrients on complex food webs, including primary and secondary producers. An important advantage of this experimental stream approach is that the effect of specific effluent concentrations on complex, benthic food webs can be studied under standardized, riverine conditions.

The objective of this project was to design and construct a transportable mesocosm for testing impacts of nutrients and contaminants from pulp mill effluents on abundance and taxonomic composition of aquatic invertebrate communities in the Athabasca River. The experimental apparatus will be used in a variety of experimental settings, and the results will be used to address the impacts of nutrients, contaminants, and their interaction on benthic invertebrate and biofilm productivity. This information is critical for assessing nutrient and contaminant impacts on biota (Questions 1A, 4A, & 5) and for preserving aquatic life and habitat (Question 6). The report describes mesocosm design, specific hydraulic characteristics, important details and procedures of installation, and initial tests of the system at the Hinton, Alberta experimental site.

ACKNOWLEDGEMENTS

We thank J. Banner, B. Christie, N. Glozier, E. Marles and J. Mollison who provided valuable assistance during the design and construction of the artificial streams. This research was supported by the Northern Rivers Basins Study and the National Hydrology Research Institute (Environment Canada). CLP was supported by a Postgraduate Scholarship from the National Sciences and Engineering Research Council of Canada (NSERC).

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1.0 INTRODUCTION

Artificial streams (i.e., mesocosms) have been used as tools for investigating ecological interactions in running waters since the 1960s (see Lamberti and Steinman 1994 for a review). This approach has been used to investigate a variety of ecological phenomena including: effects of environmental factors such as irradiance, temperature, and nutrients on algae (McIntire 1966a; McIntire 1966b; Bothwell 1988; Bothwell 1989); and to examine specific trophic relationships among algae, insects, and fish (Lamberti et al. 1987; Schlosser 1988; Lamberti et al. 1989; Culp et al. 1991; Scrimgeour et al. 1991). In the Northern Rivers Basin Study, mesocosms will be used to investigate effects of treated pulp mill effluents and nutrients on complex food webs, including primary and secondary producers.

The high degree of spatial heterogeneity and challenge of obtaining true replicates in natural environments like the Athabasca River often makes it difficult to predict or verify, quantitatively, the impacts of complex effluents on riverine biota. Therefore, an important advantage of mesocosm research lies in our ability to investigate complex, benthic food webs in model systems that simulate specific riverine conditions. It is important to recognize that the goal of mesocosm research is to simulate, rather than reproduce exactly, key aspects of the riverine environment. By locating the experimental system beside the study river, the stream mesocosm can be supplied with natural river water under ambient water temperature and light regimes. Multiple trophic level communities can be examined by seeding the mesocosms with natural substratum and biota (i.e., biofilm, invertebrates, and fish) from the river.

The objective of this project was to design and construct a transportable mesocosm for testing impacts of nutrients and contaminants from pulp mill effluents on abundance and taxonomic composition of aquatic invertebrate communities in the Athabasca River. The experimental apparatus will be used in a variety of experimental settings, and the results will be used to address impacts of nutrients, contaminants, and their interaction on benthic invertebrate and biofilm productivity. This information is critical for assessing nutrient and contaminant impacts on biota (Questions 1A, 4A & 5) and for preserving aquatic life and habitat (Question 6). The report describes mesocosm design, specific hydraulic characteristics, important details and procedures of installation, and results obtained during initial tests of the system at the Hinton, Alberta experimental site.

2.0 DESIGN AND CONSTRUCTION

This section provides a brief description of the experimental stream facility (Plate 1) and basic requirements for setting up such a system as it was constructed in the summer of 1993. The facility was designed to withstand air and water temperatures near 0°C since it would be used for experiments conducted during autumn and early spring. Throughout the description, metric units are used except for materials which are normally sold in Imperial units.

2.1 SITE REQUIREMENTS

The site for the facility requires a cleared 9 x 5 m area. The site must be accessible by road since some materials require transport by truck trailer. Availability of a water intake system and electrical power is required, otherwise generators and pumping systems must be added to the facility design. Ground at the site should be made as level as possible because a flat working surface will save a great deal of time and effort during setup of platforms and installation of plumbing. A layer of gravel or crushed rock spread over the site will drain excess water away from the working area.

2.2 STREAM FACILITY DESIGN

The experimental stream facility consists of 16 circular tanks placed in pairs on platforms. Water from the study river is pumped into a head tank reservoir and delivered through a system of pipes to the tanks. Water flow to individual tanks is controlled by a gate valve, and water movement in each stream is created by a belt-driven propeller system. Water depth in the tanks is maintained by an overflow drain and wastewater is returned to the study river.

2.2.1 Water Delivery

In Autumn 1993, water from the study river was pumped via a water intake and pumping system operated by the mill into a head tank, then gravity-fed to the streams. Water demand by the system depends upon the flow rate chosen by the experimenter. In the first run of this system, water flow was set at 2 L/min to each stream; therefore, water in excess of 32 L/min was required. The head tank was a 378 L polyethylene tank placed on a 1.22 m (4 ft) high platform. Schematic diagrams of the head tank and head tank platform are shown in Figures 1 and 2, and both are pictured in Plate 2. Water input was controlled by gate valves at each stream; therefore, the flow rate into each stream could be calibrated. The head tank and all water delivery lines were wrapped with heat tape (Plate 3) and insulated to prevent freezing (Plate 4). Figures 3 and 4 show diagrams of the system. A materials list for the water delivery system is found in Appendix 1.

2.2.2 Streams and Platforms

The streams were circular tanks (107 cm diameter; 42 inch) made out of polyester fibreglass. These were constructed by cutting 38 cm (15 inch) sections of 107 cm pipe and bonding a flat sheet of fibreglass to one end. A 25 cm (10 inch) diameter section of pipe was then centred in the larger pipe and the bottom cut out to form a standpipe. A completed stream is shown in Plate 5.

Streams were placed on eight, 74 cm (29 inch) high platforms, two to a platform. Each platform was 1.22 m x 2.44m (4 x 8 feet) long, made of 1.9 cm (3/4 inch) plywood and 7.6 x 7.6 x 0.6 cm (3 x 3 x 1/4 inch) angle aluminum. Plans for the platforms are given in Figure 5, and materials are listed in

Appendix 2. When assembling this system, care must be taken to ensure that the platforms are completely level and that pairs of tables sharing 2.54 cm (1 inch) feed lines are level with each other.

2.2.3 Wastewater System

A 3.5 cm (1 3/8 inch) drain hole was cut in the standpipe approximately 27 cm above the bottom of the tank. Height of this drain determined water depth in the streams. A 2.54 cm (1 inch) MTxS male adapter served as the drain on the inside wall of the tank. The adapter was screened with fibreglass door screen (Plate 6 a) and was screwed into a 1 inch elbow on the other side of the tank wall (Plate 6 b). Rubber gaskets placed on either side of the tank wall prevented leakage. Water flowing into the drain passed through a 1 inch pipe running vertically down through the platform (Figure 6). The 2.54 cm (1 inch) drain lines emptied into 5.1 cm (2 inch) drain lines which ran under the platforms (Plate 7 a & b) and were connected to a wooden trough (Plate 8). The 5.1 cm (2 inch) drain lines were heat taped and insulated. Wastewater from the troughs was returned to the study river through a length of 10.2 cm (4 inch) Big-O hose (Plate 9). A materials list for the wastewater system is provided in Appendix 3.

2.2.4 Motor and Propeller System

Current velocity in the stream was created by a belt-driven propeller system. The motor assembly was comprised of a geared-head motor (250 rpm, 1/40 amp) driving a 22.6 mm pulley. A flat drive belt transmitted power to a 49.3 mm pulley mounted on the propeller shaft. The motor and associated electronics were mounted on an aluminum frame in a weather proof enclosure. This frame clamped to the top, outside edge of the circular tank (Plate 10). A 16 mm x 230 mm long, copper strut extending downward from the aluminum frame held the propeller shaft, bushing, and grease seal. A grease nipple at the top of this tube allowed for lubrication of the propeller shaft and bushing. The propeller was a 22.8 cm (9 inch) aluminum fan blade which rotated at a no-load speed of 115 rpm. Materials for the motor and propeller system are listed in Appendix 4.

2.2.5 Contaminant Delivery System

Contaminants were delivered continuously to individual streams by peristaltic pumps and a series of insulated tubes for solution delivery. In the first run of this system, 2 Masterflex L/S Nema, type 13, wash down controllers and cartridge pump heads were used to deliver solutions to ten of the 16 streams. Pumps were kept in insulated boxes to keep them within approved operating temperatures (Plate 11). Solutions were stored in insulated containers (Plate 12) and immersion heaters were used to heat the solutions to approximately 27 °C. Tubes carrying contaminant solutions were run through 1.9 cm (3/4 inch), foam, pipe insulation to the streams. The tubes were then fed into small holes drilled into the water delivery spouts. Heating of solutions and insulation of all supply lines is recommended to prevent the thin supply lines (< 2 mm) from freezing.

2.2.6 Electrical System

If power is supplied by an existing electrical source, a step-down transformer may be required to deliver correct voltage and amperage to the experimental facility. In the autumn 1993 experiments, the 600 volt a.c. electrical power supplied by the mill was stepped down by a 7.5 KVA distribution transformer which provided four 120 volt, 15 amp circuits. Each of the circuits was used as follows: two circuits, consisting of four duplex outlets each, were needed to power the circulation motors; one circuit of two duplex outlets supplied power to the metering pumps; and one circuit of two duplex outlets was used for other needs as they arose.

3.0 OPERATION

This section provides a brief description of the operation of the artificial stream system as it was used in the initial run of the system during autumn, 1993.

3.1 SUBSTRATUM

A variety of substrata types including natural and artificial materials can be used in the mesocosms. In our initial operation of this system, the bottom of each stream was covered with a thin layer of thoroughly washed, crushed rock. One hundred and sixty stones (mean surface area = 535 cm^2) were collected from the study river, and ten were placed in each stream on top of the crushed rock, as illustrated in Plate 13. Using substratum from the study river provided a natural community of biofilm and invertebrates for experimental tests that incorporate multiple trophic levels. Porcelain tiles (23.5 cm^2) were used to provide a standardized substratum to compare biofilm development and accumulation. Two sets of tiles were used; one set was placed on top of the crushed rock, the other was suspended above the bottom on aluminum bars (Plate 14).

3.2 WATER DEPTH

Water depth in the streams was controlled by adjusting the height of the drain tube. In the initial experiment, mean water depth over gravel in the streams was 27 cm (x = 26.9 cm, SE = 0.09) and 22 cm (x = 22.5, SE = 0.14) over rocks. Note that water depths in this experiment were measured at the highest point of each rock in the stream. Water depth over suspended tiles was 10 cm (10.0 cm, SE = 0.6).

3.3 CURRENT VELOCITY AND CONTAMINANT MIXING

A test stream was set up in the laboratory in order to determine the range of water velocities that could be produced in the streams. In this test, the stream substratum was similar to that used in the autumn 1993 experiments, and velocity was measured with a Nixon Instruments velocity meter. Specifically, the substratum consisted of a thin layer of gravel upon which larger rocks were placed. The test stream did not contain tiles suspended over the stream bottom. Measurements were taken at 21 locations around the stream at three depths: immediately below the surface, at the mid-point of the water column, and just above the highest point of each rock. For the tests, water depth in the stream was approximately 31 cm. Mean water velocity, measured approximately 4 cm below the water surface, was 0.196 m/sec (n=21, SE = 0.029), and ranged from 0.006 to 0.479 m/sec. Average mid-water velocity was 0.20 m/sec (n=21, SE = 0.0223) with velocities ranging from 0.021 to 0.344 m/sec. Velocities just above rock surfaces ranged from 0.006 to 0.378 m/sec with a mean velocity of 0.225 m/sec (n=25, SE = 0.0194). During the autumn experiment, we suspended tiles on aluminum bars above the stream bottom and found that these created enough drag to reduce overall current velocity in streams relative to our laboratory tests. The mean velocity in streams at the mill site was 0.26 m/sec (n= 150, SE = 0.014, mean depth = 25 cm). Observations of dye traces indicate that contaminants mix within the first quarter of stream length (Plate 15).

3.4 HYDRAULIC RESIDENCE TIME AND WATER TEMPERATURES

Hydraulic residence time in streams was adjusted by changing the inflow rate. In the initial run of this system, inflow was set to 2 L/min. The tanks have a volume of 227 L resulting in a residence time of just under 2 h.

Water temperature was monitored by placing a Ryan thermograph in one of the streams and another in the head tank (Plate 16). Temperatures in the head tank reflect temperatures in the incoming river water. In contrast, relatively long residence times in streams resulted in some heating or cooling of water depending upon ambient air temperatures. Figure 7 shows heating and cooling of water in experimental streams relative to incoming water over a 72 h period.

3.5 MAINTENANCE

The stream system required a moderate amount of regular maintenance as motors had to be inspected daily for loose or misaligned belts. Loose belts were commonplace, particularly in the first three weeks of operation but were relatively easy to fix. In addition, motors were lubricated with non-toxic grease every three days to prevent seizing of propeller shafts. Leaves falling into the streams during autumn had to be removed daily as they caught on the propellers and caused them to become unbalanced and rotate unevenly. Drain screens were cleaned daily. The 4 inch water delivery lines were flushed on a weekly basis to remove any build-up of sand that settled in the lines (Plate 17). Finally, contaminant delivery lines had to be inspected for blockages and tubing changed as required, this was only a problem in lines carrying pulp mill effluent.

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5.0 FIGURES

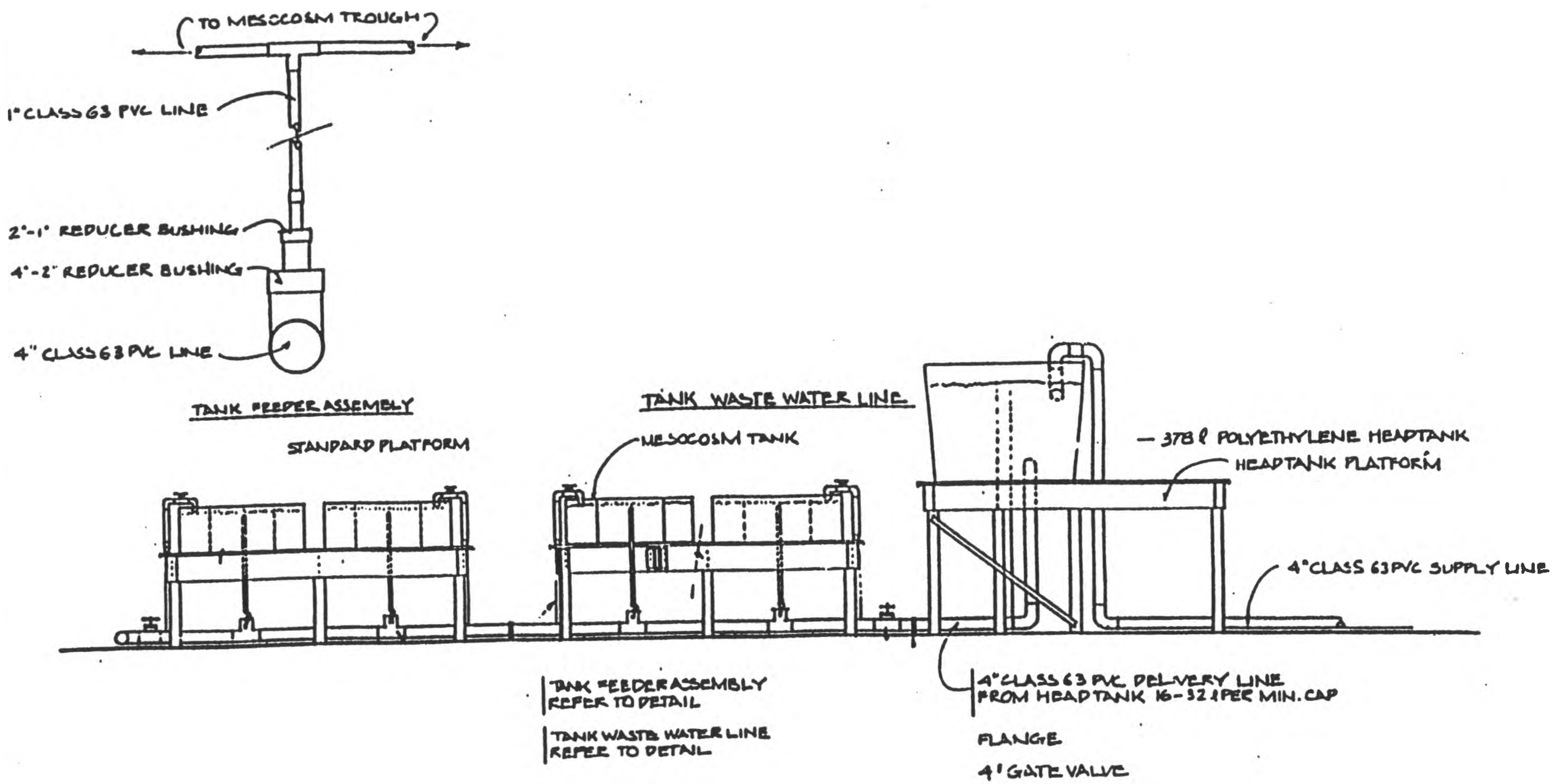


Figure 1. Side view of experimental stream facility showing: head tank and head tank platform, stream tanks and stream platforms, and associated plumbing for the water delivery and wastewater systems. Note inset of tank feeder assembly.

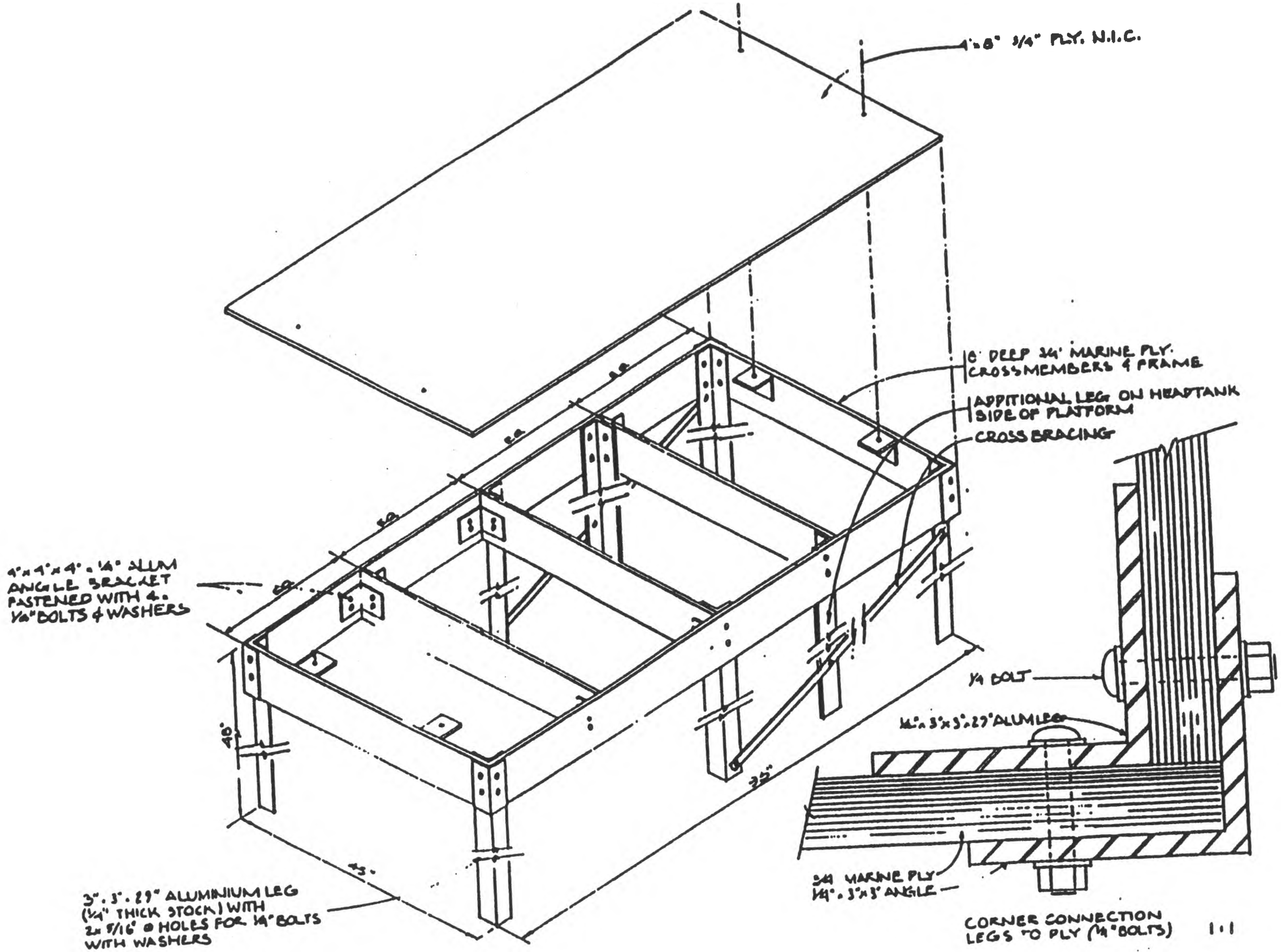


Figure 2. Schematic diagram of the head tank platform used to support the head tank for the experimental stream facility.

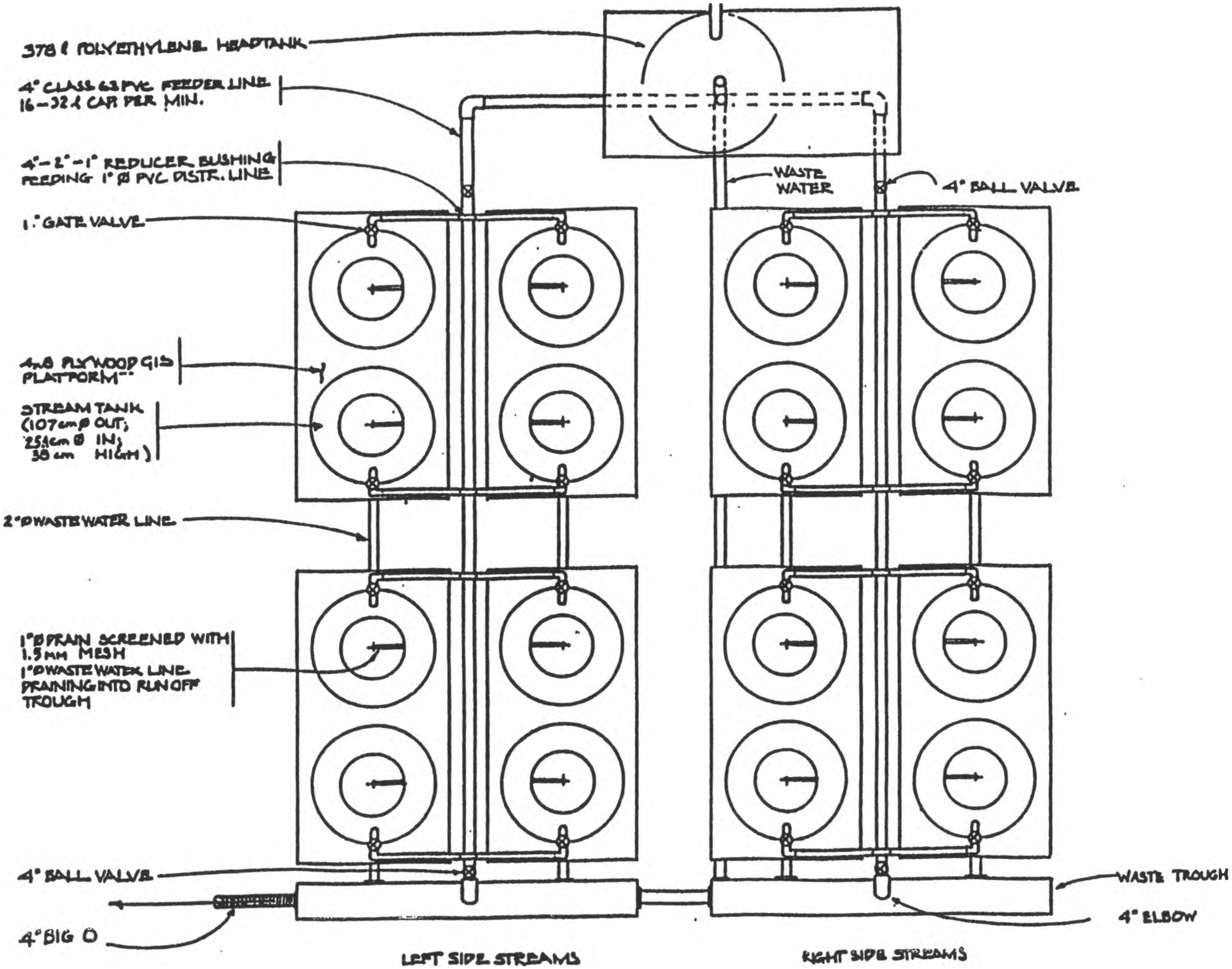


Figure 3. Overhead view of experimental stream facility showing plumbing used for water delivery and waste-water systems.

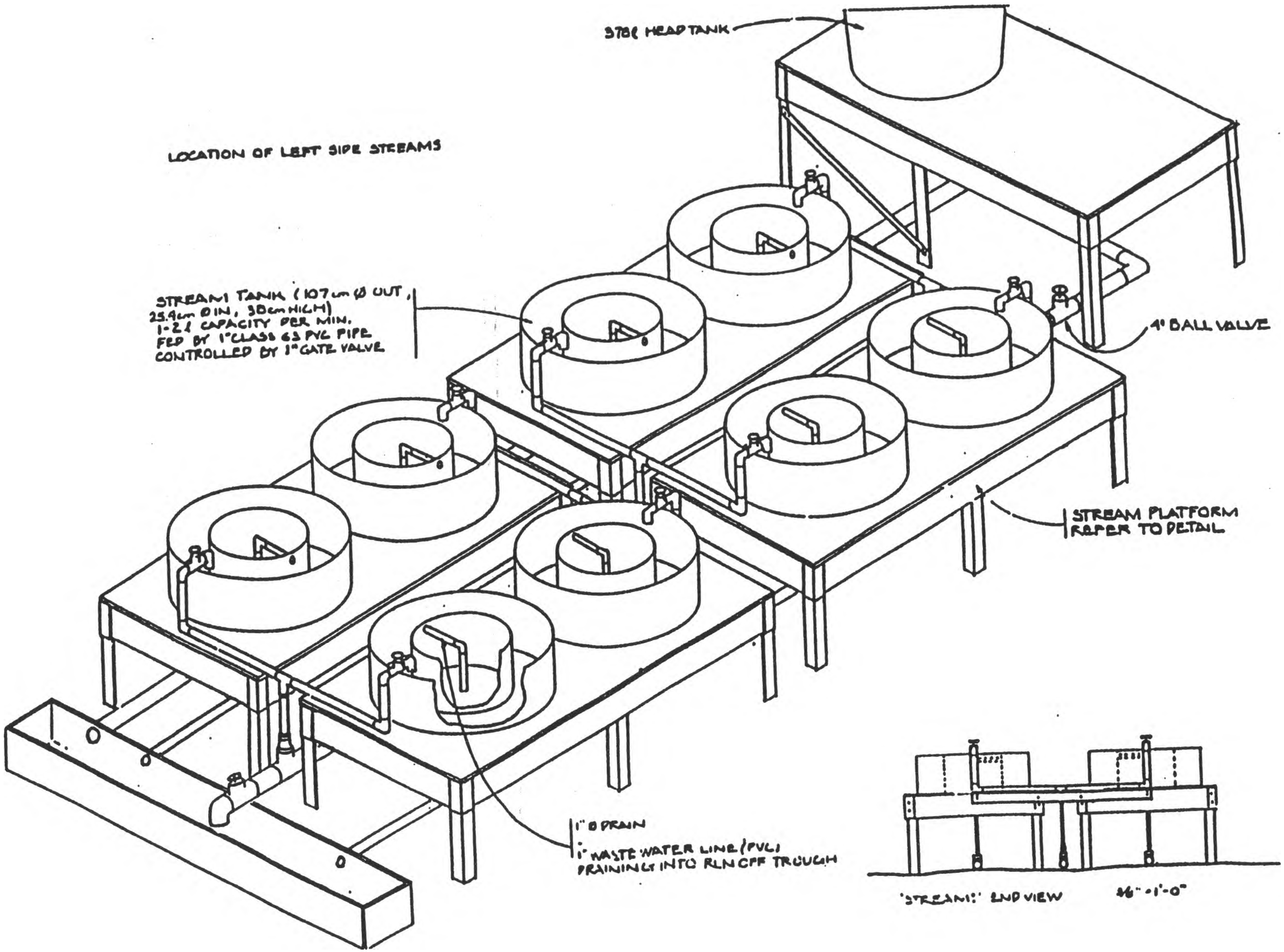


Figure 4. Oblique view of stream facility showing water delivery and wastewater systems. Note inset of stream end view.

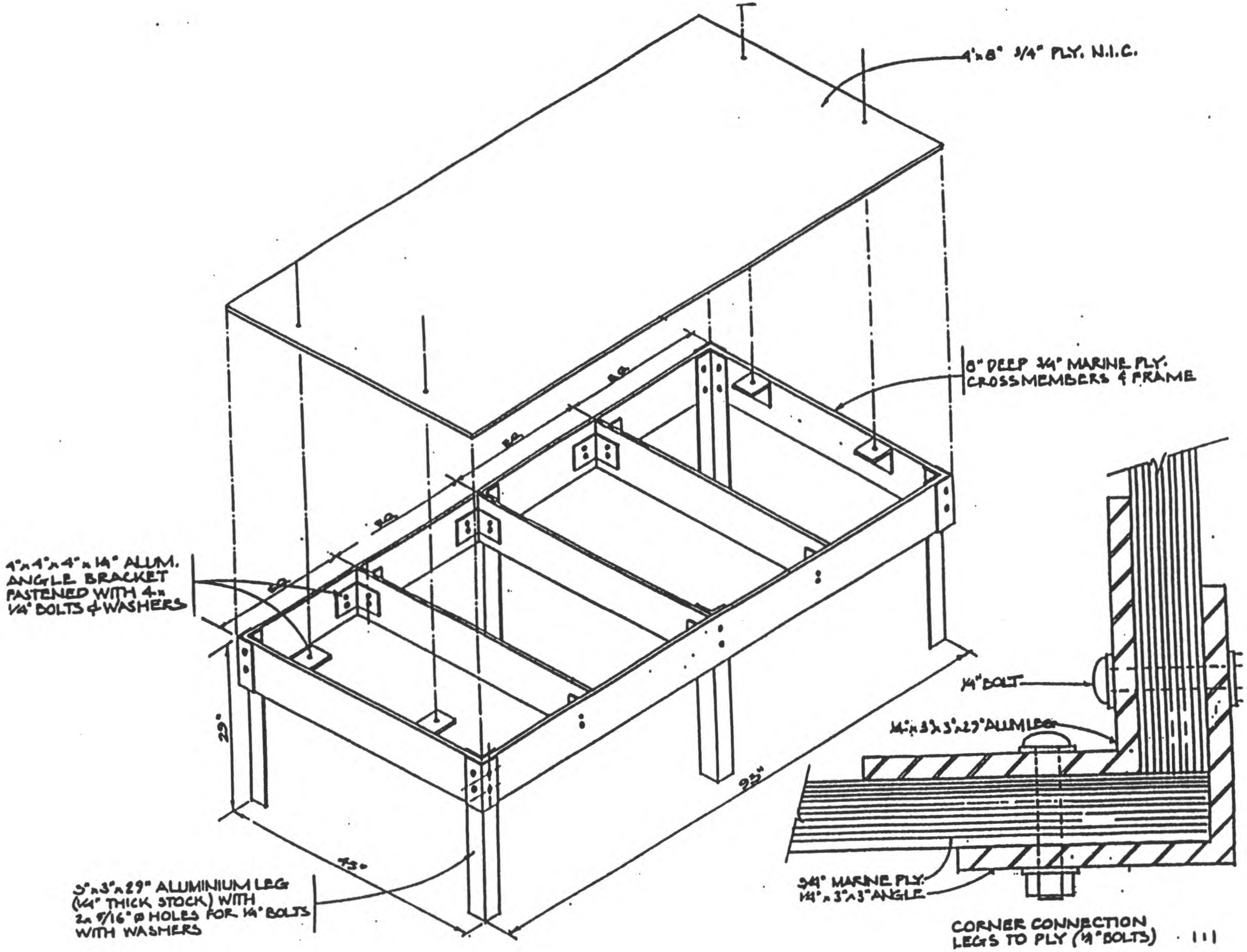


Figure 5. Schematic diagram of a stream platform used to support two stream tanks.

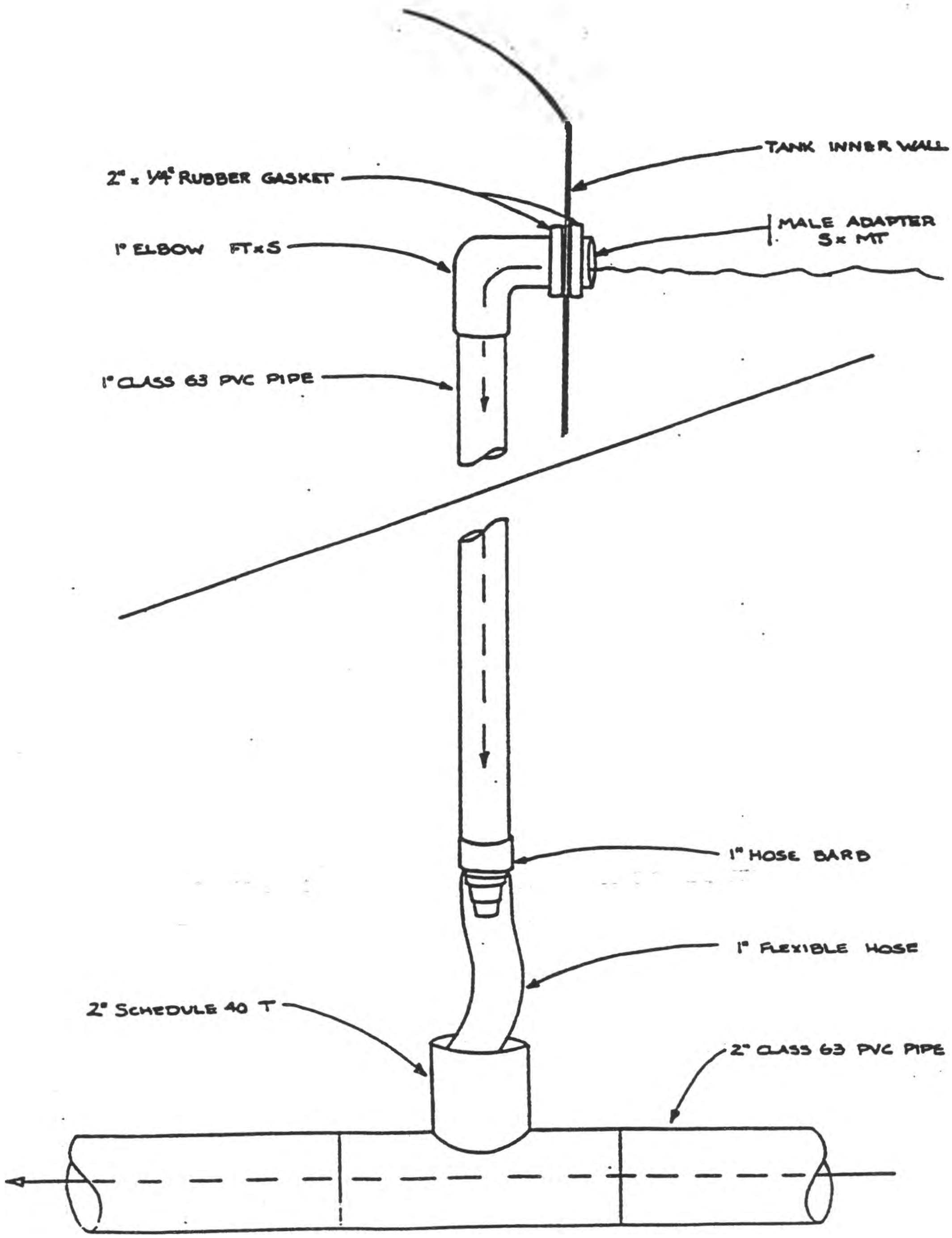


Figure 6. **Close-up, schematic view of the plumbing used for the drain line from each stream tank and connection to the shared 2 inch drain line running under the platforms.**

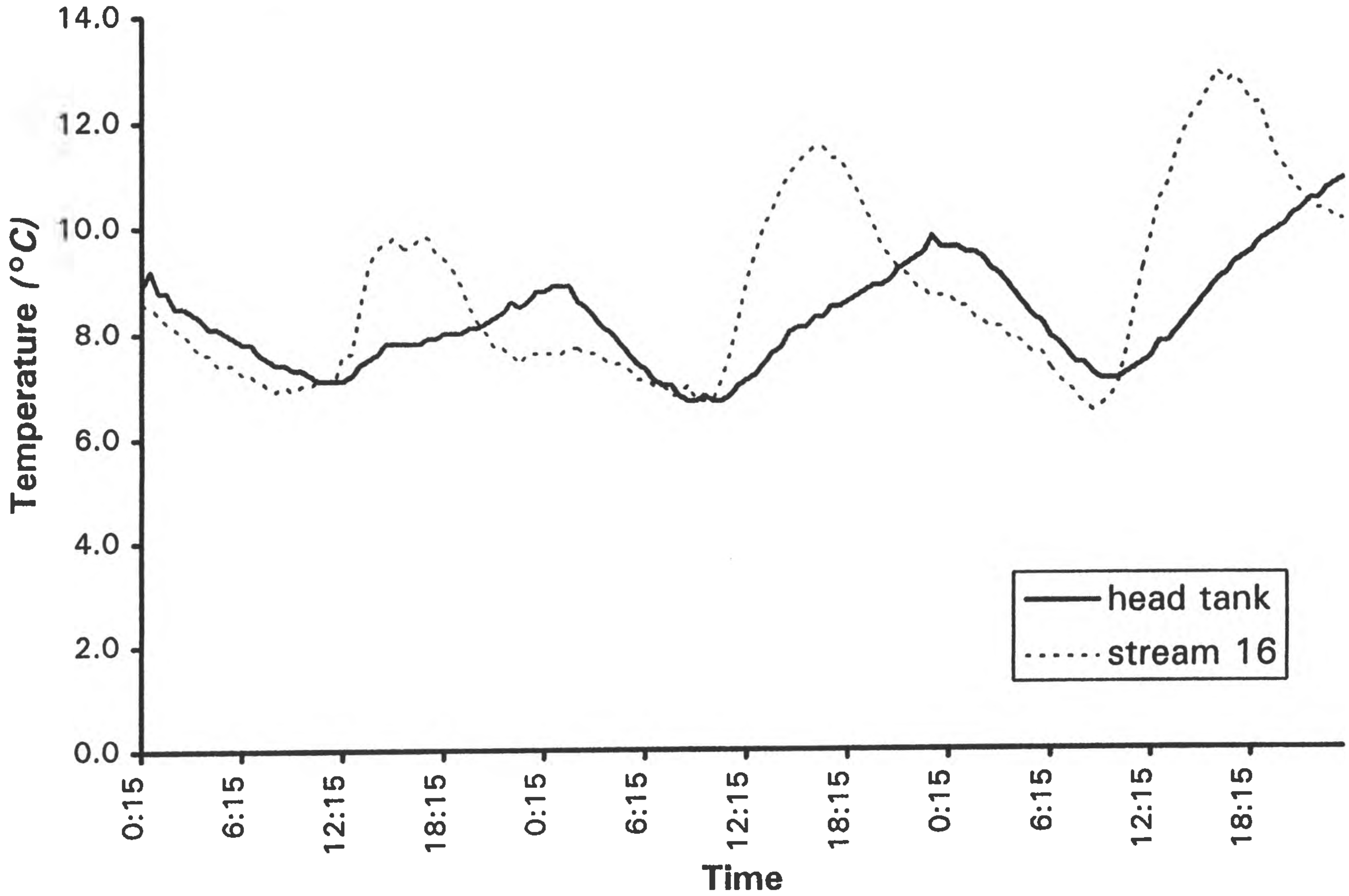


Figure 7. **Variation in water temperature in experimental streams relative to ambient river water temperature in the head tank over a 72 hour period.**

6.0 PLATES

Plate 1. View of experimental stream facility assembled at Hinton, Alberta (autumn 1993).

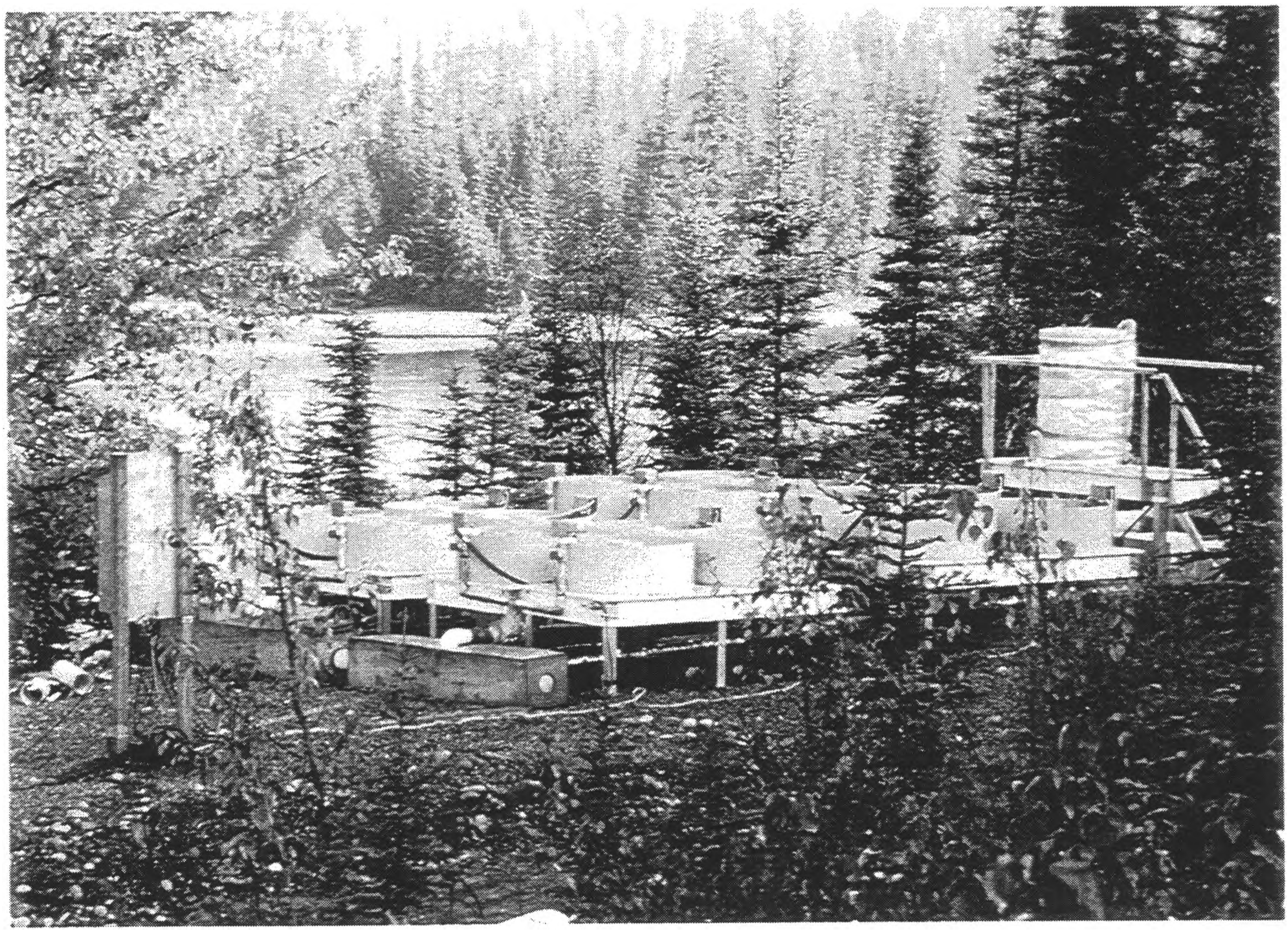


Plate 2. Head tank and head tank platform used for experimental stream facility.

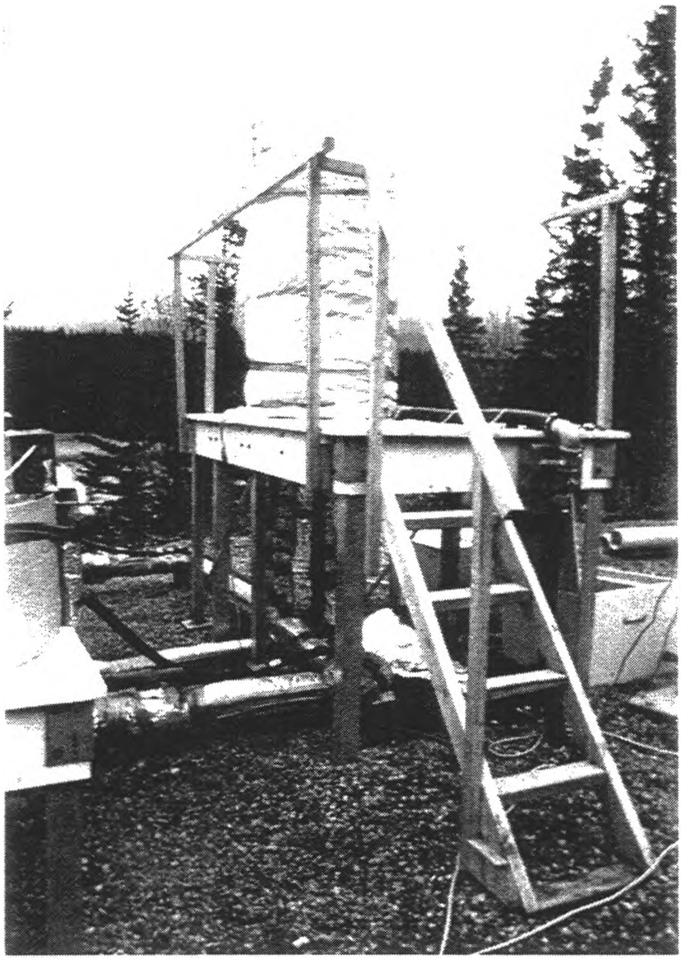


Plate 3: Water delivery line wrapped with heat tape to prevent freezing.

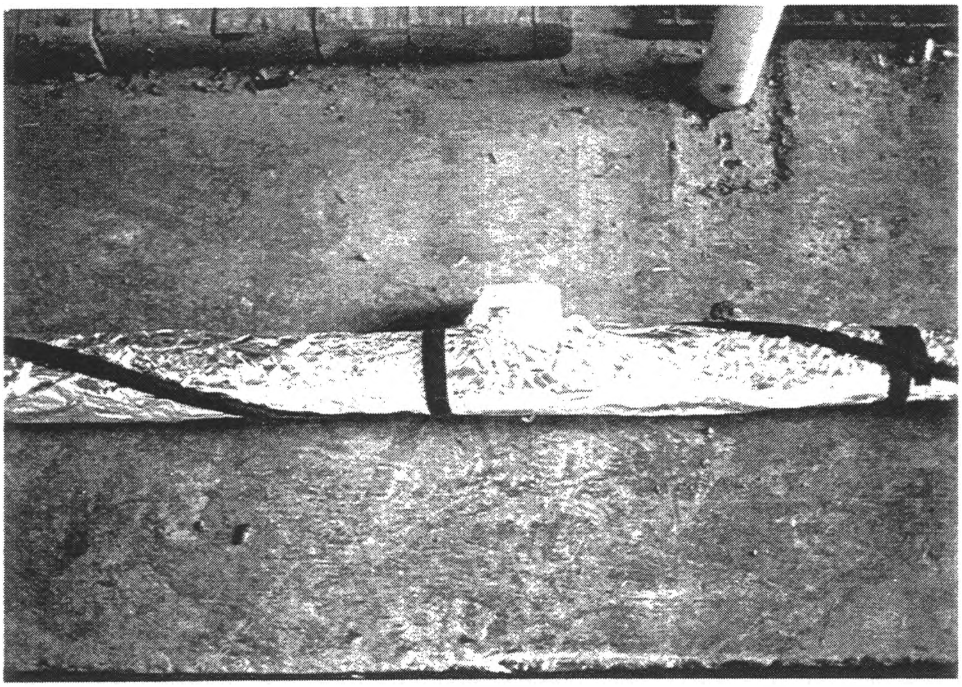


Plate 4. Insulating head tank to prevent freezing.

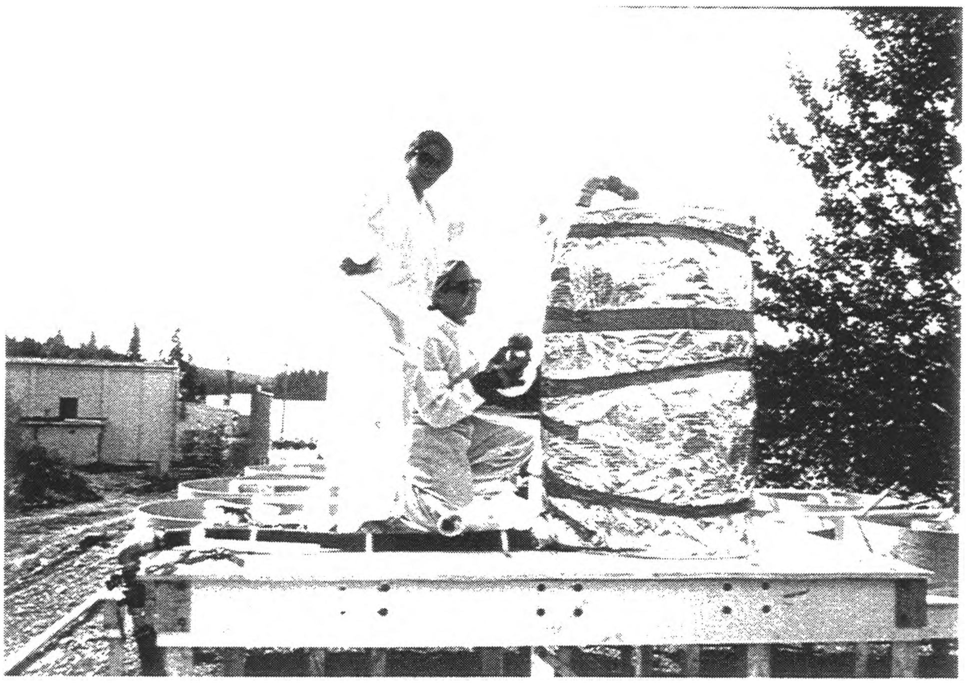


Plate 5. Completed stream tank showing: water intake, centre standpipe with drain, and motor assembly (attached to side of tank).

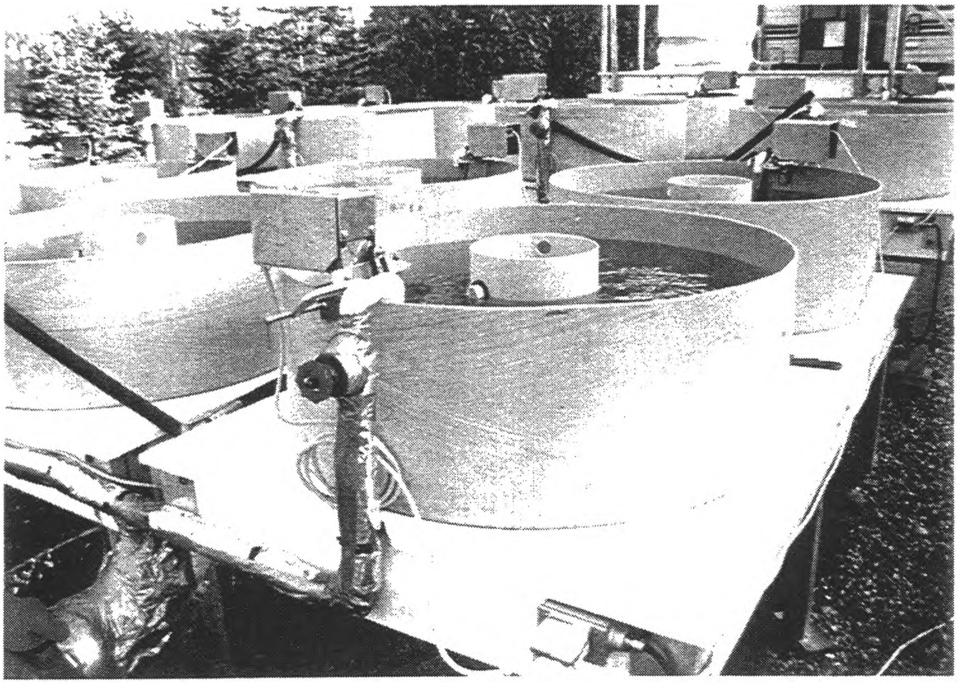


Plate 6. Drain assembly showing (a) fibreglass screen and (b) elbow connection.

a

b

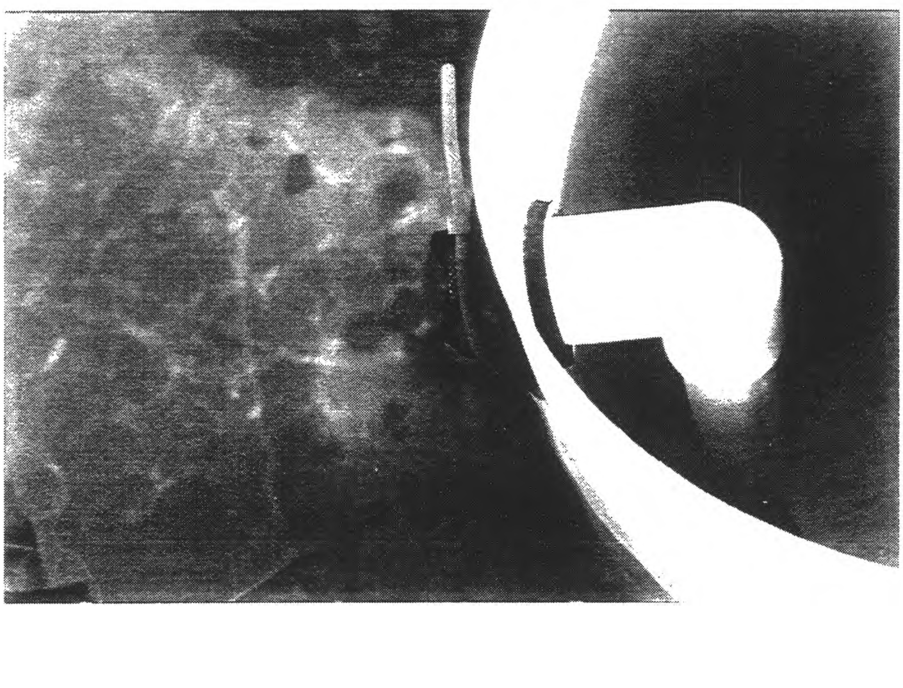
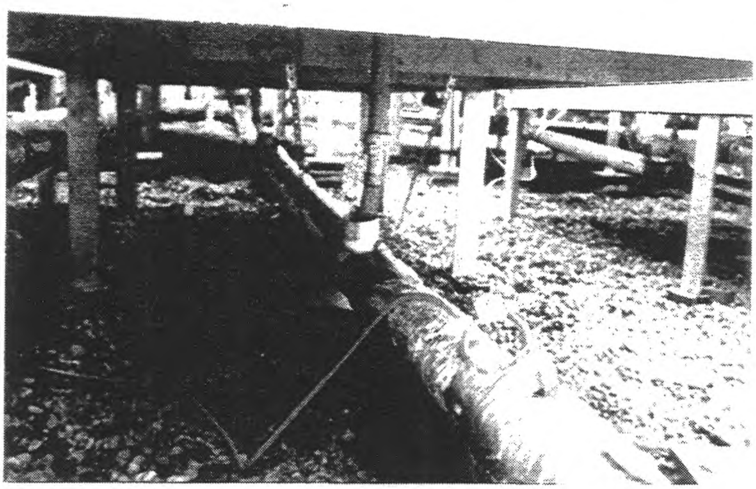


Plate 7. Waste lines showing (a) 1 inch drain lines from each tank and their (b) connection to the 2 inch drain lines running under the platforms. Note insulation of 2 inch drain lines.

a



b

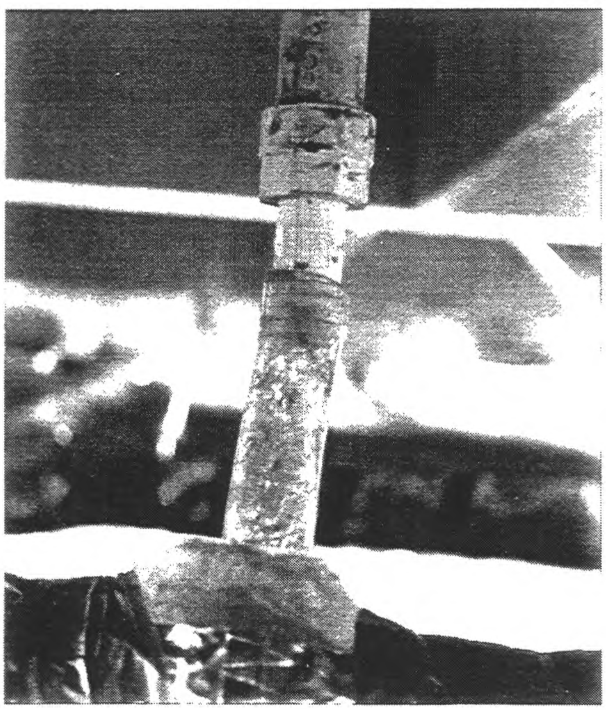
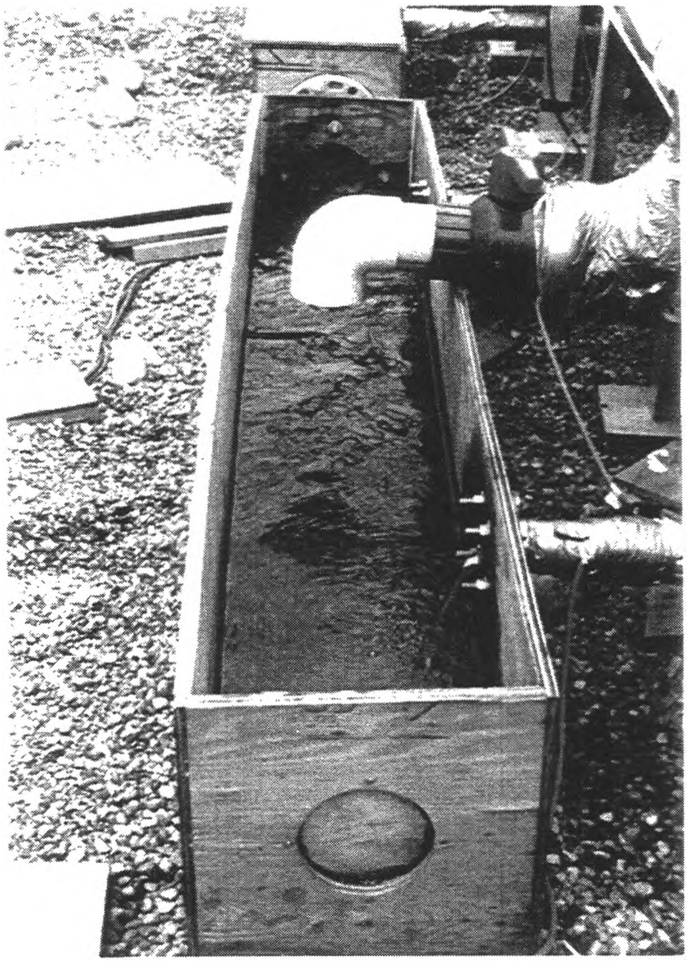


Plate 8: 2 inch drain line and wooden collection trough located at downstream end of the stream facility.



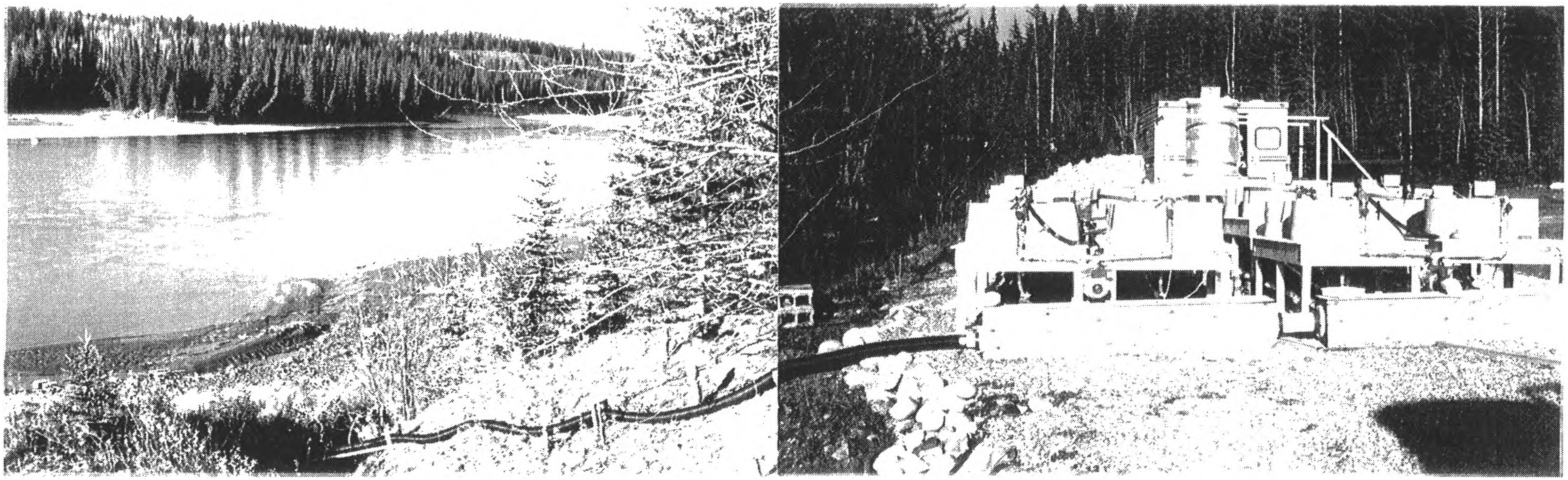


Plate 9. View of completed stream facility showing: head tank and head tank platform, streams and stream platforms, motor assemblies, drain lines and collection troughs, and 4 inch Big-O hose used to return wastewater to the study river.

Plate 10. Motor assembly and propeller system showing: attachment to tank wall, copper strut and grease nipple, belt and pulley system, and propeller shaft and propeller.

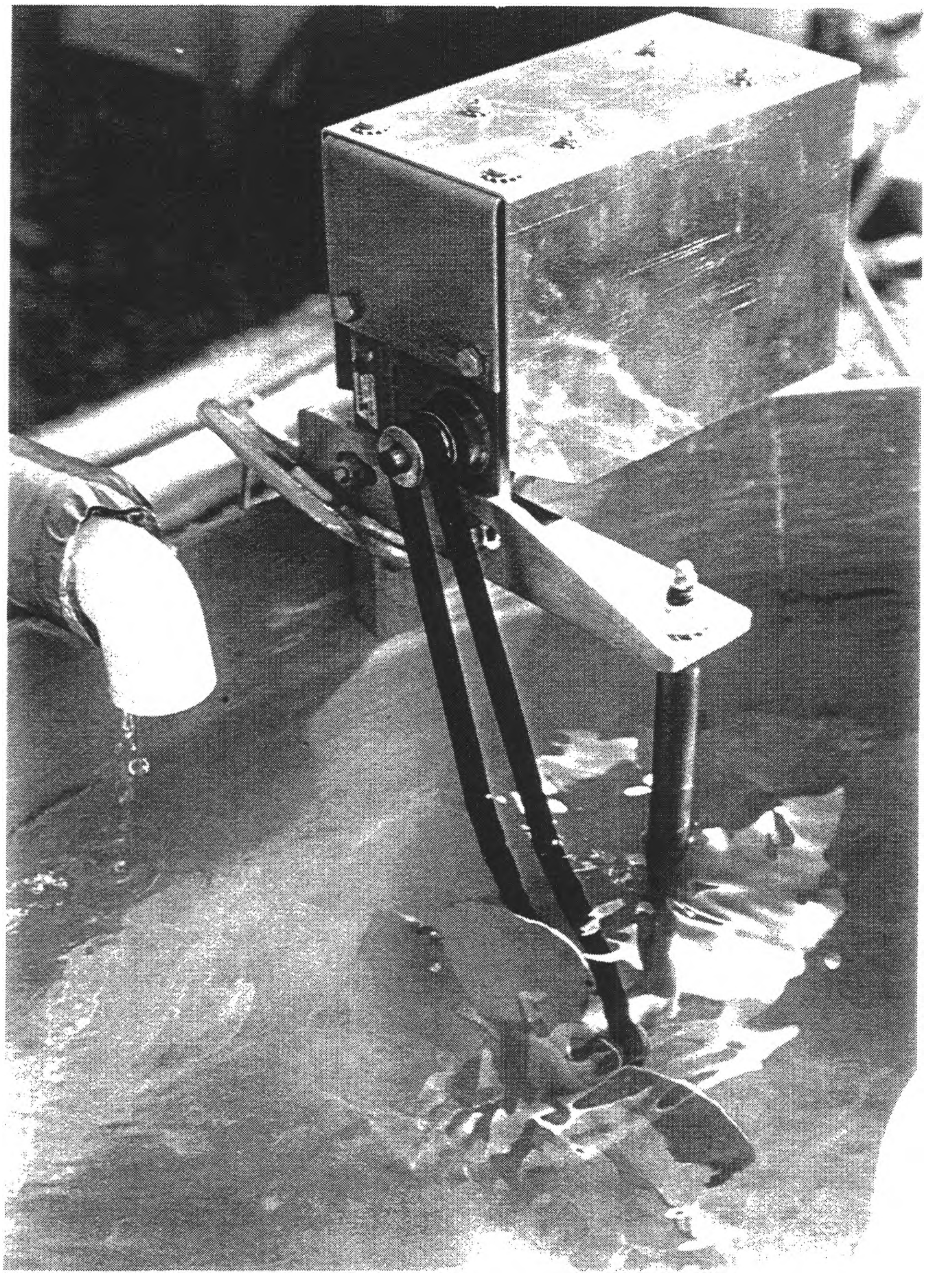


Plate 11. Contaminant solution pump and insulated holding box used to maintain the pump within approved operating temperatures.

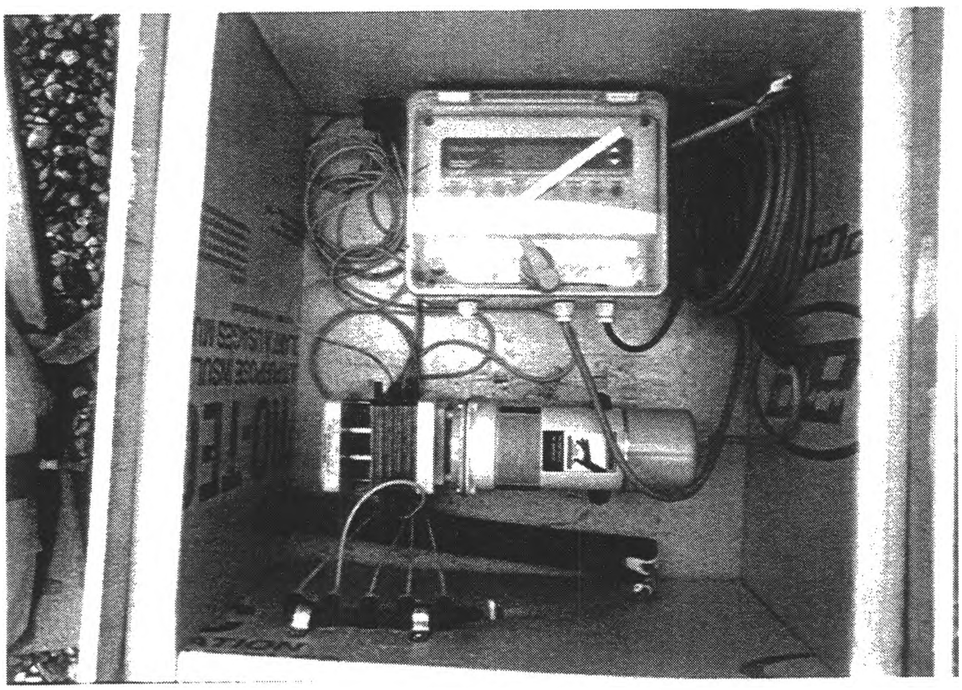


Plate 12. Insulated storage container used for contaminant solutions.

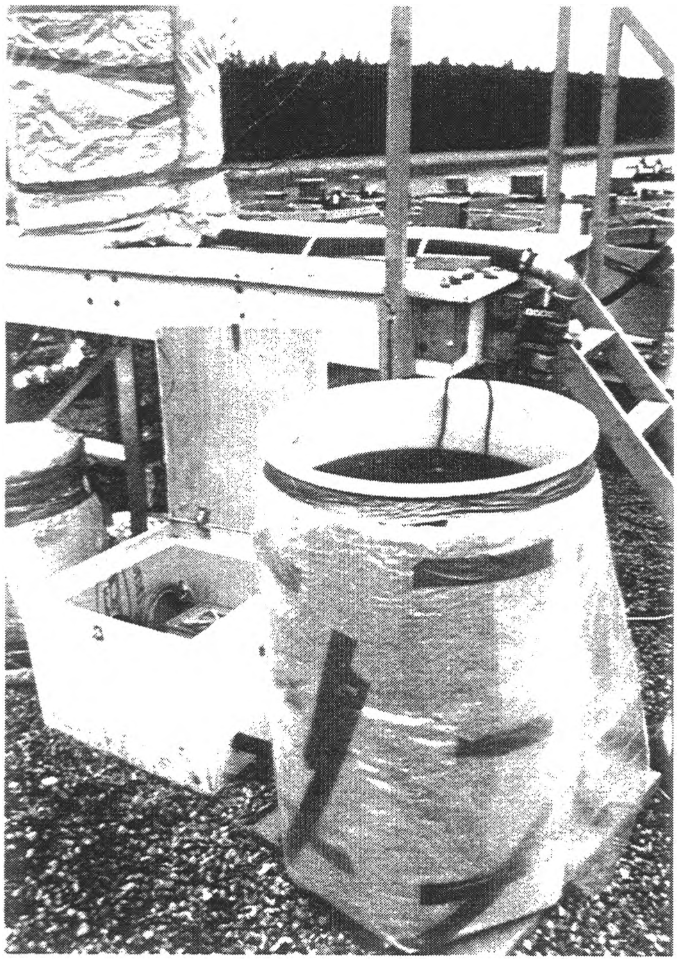


Plate 13. Placement of stones in the artificial streams. Stones were collected from the Athabasca River upstream of the mill effluent outfall.

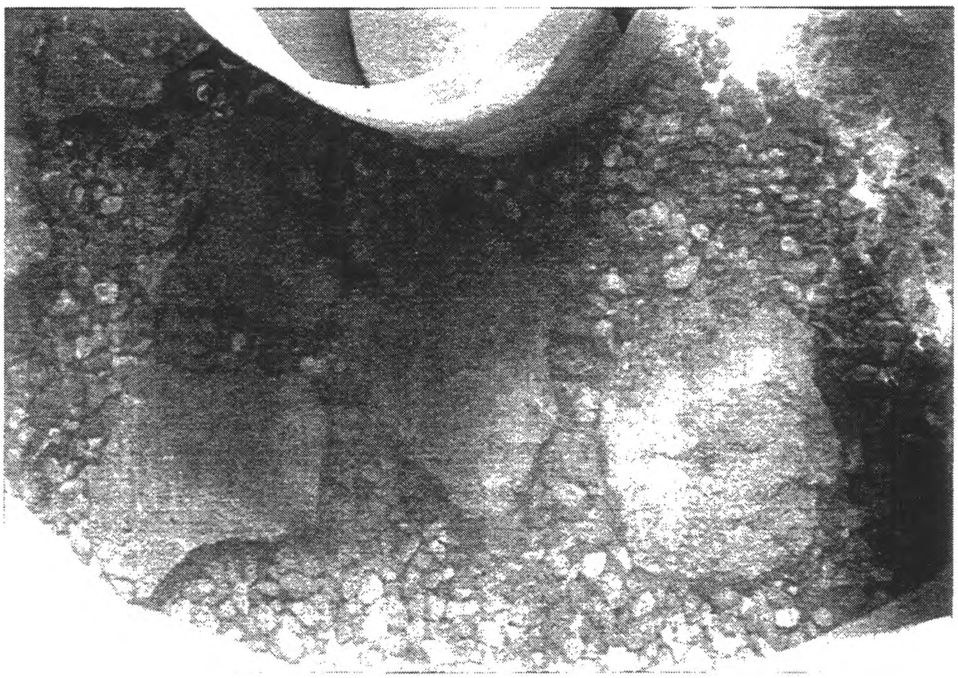


Plate 14. Experimental streams showing the placement of porcelain tiles on the gravel and suspended from aluminum bars.

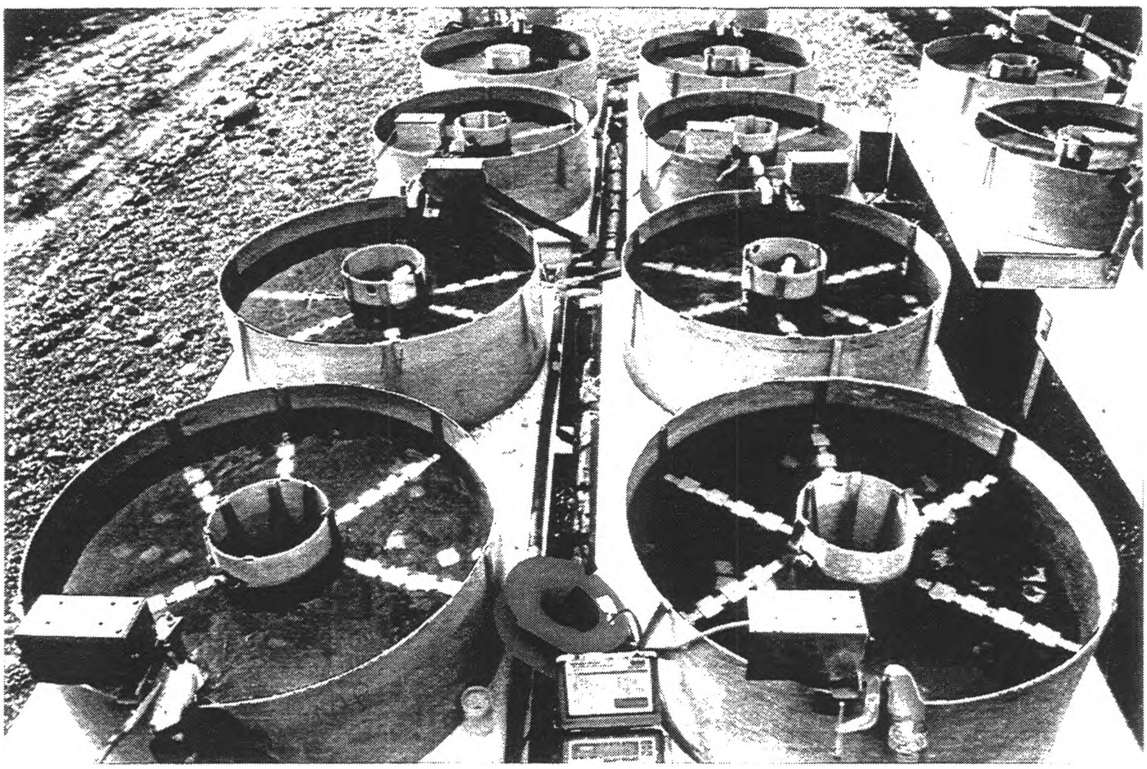
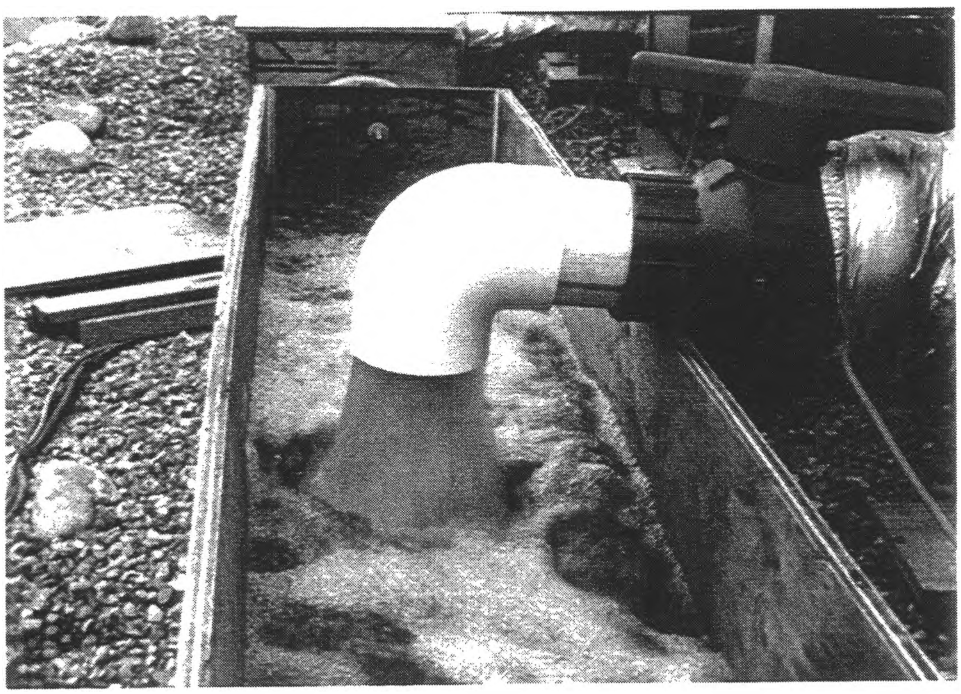


Plate 15. Dye trace showing mixing within first quarter of stream length.

Plate 16. Ryan thermograph used to monitor stream temperature.

Plate 17. Four inch water delivery line being flushed into wooden trough at downstream end of facility.



Appendix A. Terms of Reference for NRBS Contract Number 2611-C1.

NORTHERN RIVER BASINS STUDY

ASSIGNMENT NO. 5 - TERMS OF REFERENCE

Project 2611-C1: Design of Invertebrate Artificial Stream

I. Introduction

The purpose of this project is to develop a design for artificial streams for testing of the impacts of nutrients and contaminants from pulp mill effluents on the abundance and taxonomic composition of aquatic invertebrate communities found in the Peace, Athabasca and Slave river basins.

II. Requirements

A portable artificial stream system is to be designed to undertake experiments to determine the relationship between nutrients, contaminants or both on the abundance and taxonomic composition of benthic aquatic invertebrates. The system should consist of 16 artificial streams which can be lined with natural substrates and which are capable of supporting and sustaining a stream insect community. The stream system is to include a pumping system to deliver water from the river to the system, a delivery system for mixing water with specific concentrations of nutrients and/or contaminants, and a data logger system for continuous monitoring of environmental parameters. The system is to be designed to operate year-round. The design for the artificial streams is to be completed by November 30th, 1993.

III. Reporting Requirements

A draft report outlining the design of the artificial streams is to be submitted to the component coordinator by January 3, 1994. Three weeks after receipt of review comments on the draft report, the consultant is to submit one unbound, camera-ready copy and five cerlox bound copies of the final report to the component coordinator.

IV. Project Administration

The component coordinator for this project is:

Greg Wagner
Northern River Basins Study
690 Standard Life Centre
10405 Jasper Avenue
Edmonton, Alberta
T5J 3N4 phone: (403) 427-1742, fax: (403) 422-3055

Appendix B. Components of Artificial Stream.

(1) Materials list for water delivery system.

Description	Dimension	Quantity
Class 63 PVC pipe	4 "	110'
Sch 40 PVC tee	4"	9
Sch 40 PVC 90 deg. elbow	4"	6
PVC ball valve	4"	4
PVC reducer bushing	4" to 2"	8
PVC reducer bushing	2" to 1"	8
Class 63 PVC pipe	1"	60'
Gate valve	1"	16
Sch 40 PVC 90 deg. elbow	1"	48
Sch 40 PVC tee	1"	8
PVC pipe flange with gasket	4"	1
Vanstone flange with gasket	4"	2
Polyethylene tank with lid	378 litre	1
Bolts	3 1/2"	18

(2) Materials list for platforms (includes materials for head tank platform).

Description	Dimension	Quantity
3/4" plywood	4' x 8'	9
3/4" plywood	4' x 8"	18
3/4" plywood	8' x 8"	18
Aluminum angle brackets	4"x 4"x 4"x 1/4"	162
Aluminum angle stock	3" x 3"x 1/4"	120'
Aluminum stock	1" x 1/4"	24'
Bolts with washers	1/4"	56
Latex paint		

(3) **Materials list for wastewater system.**

Description	Dimension	Quantity
Class 63 PVC pipe	2"	70'
Sch 40 PVC pipe caps	2"	4
Sch 40 PVC tee	2"	16
PVC socket flanges with gasket	2"	4
Flexible tubing (silicone recommended)	1"	16'
Class 64 PVC pipe	1"	32'
Sch 40 PVC 90 deg. elbow FTxS	1"	16
Sch 40 PVC male adapter SxMT	1"	16
Circular rubber gasket	2"x1/4" with 1" hole	32
3/4' plywood	4' x 8'	8
Vanstone flanges with gaskets	6"	2
Vanstone flanges with gaskets	4"	1
Class 63 PVC pipe	6"	2'
Flexible pipe strapping		
Big O hose	4"	*

*quantity dependent upon distance to receiving water

(4) **Materials list for motors**

Description	Dimension	Quantity
250 RPM, 1/10 H.P., Geared-head 110 V motor		1
1591 DBU Hammond box		1
Pulley	22.6 mm diameter	1
Pulley	49.3 mm diameter	1
Copper tube	16 mm x 230 mm	1
Copper tube	8 mm x 230 mm	1
Brass bar	3" x 3/4"	1
Stainless steel shaft	4" x 1/4"	1
Aluminum fan blade	9"	1
Grease nipple		1
C/R oil seal		1
Flat belt	14.5" x 0.5"	1
Set screws	10-32	2
NC bolt	1/2" x 1"	1
Nuts	1/2"	2
Lock washer	1/2"	1
SJTW wire	8' 16-3 gauge	1
U ground plug		1
Sheet aluminum	8" x 15" x 0.032"	1
Angle aluminum	8" x 1.5" x 2"	1
Aluminum box tube	3" piece of 1"x1"x1/8"	1
Fuse holder		1
Fuse	1/2 amp	1