DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT

LAKE TOOLIBIN

WEST TOOLIBIN FLATS DRAINAGE

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JIM DAVIES & ASSOCIATES
CONSULTANT HYDROLOGISTS

PO BOX 117 SUBIACO WA 6008
TEL: 388 2436 FAX: 381 9279

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1.0 INTRODUCTION

The Lake Toolibin Recovery Plan highlights improved surface drainage of the Toolibin Flats as a high priority. The Department of Conservation and Land Management (CALM) has requested assistance from the Department of Agriculture with respect to appropriate drainage design for the Flats.

Jim Davies & Associates has been commissioned by CALM to assess several drainage options for the Toolibin Flats and to prepare detailed designs of the option chosen by the landholders as most suitable (Jim Davies & Associates, 1994a). This report gives a detailed description of the drainage option selected by landholders.

Reconstruction of four floodways on Shire roads is proposed. The detailed design of these is beyond the scope of this report and is the responsibility of the Shire of Wickepin. The preferred option for floodways 1 and 3 on South Wogolin Road is a cement stabilised gravel floodway. Culverts will probably cause a greater backwater upstream and more inundation beyond the proposed drainage system. Floodways 2 and 4 on Brown Road, which is a summer road only, can probably be built to a lesser standard.

The report presents estimation of design flows in the proposed drains, assessment of location for the drains, required drain cross sections and sufficient information to call for tenders for drain construction. Several site visits were made to confirm acceptable drain location and types with landholders.

2.0 DESCRIPTION OF DRAINAGE PROPOSAL

2.1. General

The proposed drainage system has been designed to decrease waterlogging and salinity on the West Toolibin Flats and minimize negative impact on CALM Reserves. The drainage system provides a continuous drainage line which utilises existing structures and natural drainage lines and takes account of proposed field drainage (Walsh, 1994). When combined with other elements of the Lake Toolibin Recovery Plan, surface drainage of the Western Flats will likely assist in long-term improvements to current trends that threaten the environmental health of Lake Toolibin.

Flow from the western flats remains divided into 'fresh' and 'brackish' streams, with flow entering the CALM Reserve Nos. 9617 and 27286, at two locations:

1. at the end of the existing CALM drain; and
2. at the natural drainage line to Lake Dulbining, west of Oval Road.

Refer to Figure 1 for layout of drainage, Figure 2 for location of cross sections, Figures 3 & 4 for drain long sections, and Figures 5 to 9 for cross sections. Drain design flows are presented as Table 1. The dimensions of drains and floodways are presented in Table 2 and appear on Figures 5 to 9. Drain segment numbers shown on these figures are given in brackets in the text of the report.

2.2 Western Drainage Branch

2.2.1 General:

Flow from Keith's catchment enters the main drainage line on the northern side of South Wogolin Road. Flow passes down a drain (1aW) in the northern road reserve up to Floodway 1, which directs flow south along a drain (2) to the property boundary between Miller's and Sims', and joins with flow from Fran's catchment, the largest individual catchment of the West Toolibin catchment area. Flow continues along the natural drainage line through the remnant vegetation. Flow continues along a drain running south-east (3b) and then south through an improved drain (8a) to cross Brown Road at the existing floodway (Floodway 2) and then to continue south. A new drain (8b) will continue south-west through the CALM Reserve 9617 to join the natural drainage line into Dulbining Lake.

2.2.2 Drain Segment 1aW:

Drain 1aW extends west-east, a distance of 500 m, from where flow from Keith's catchment first reaches South Wogolin Road to Floodway 1. Drain 1aW, the existing drain in the northern verge of South Wogolin Road, is upgraded to carry the design flow, with spoil placed on the northern side of the drain.

2.2.3 Floodway 1:

The floodway will be constructed to allow flow to pass across South Wogolin Road into Keith Miller's property. Spoil in the road verge will be placed to allow high flows to pass east into drain 1aE. Refer to Figure 6 for detail of Floodway 1. The natural drainage line requires grading for about 100 m south of the floodway.

2.2.4 Drain Segment 2:

Drain segment 2 will direct flow which crosses South Wogolin Road at Floodway 1 south into remnant vegetation to join with flow from Fran's catchment. The drain will run north-south along the fenceline between Sims' and Miller's properties until approximately 80 m into the remnant vegetation, then turn south-east for another 200 m. To maximise the existing grade the drain will not be excavated until the point where the natural drainage line approaches the fenceline. In this northern area the excavated channel will not provide sufficient material for the bank, hence soil will be removed from east of the drain and subsurface clays will be used to construct a bank. Topsoil will be replaced to create a stable surface. The excavated drain will begin on the western side of the fence and will cross over to the eastern side, approximately 280 m south of South Wogolin Road. The point where the drain crosses the fenceline has been chosen to minimise disruption to trees in the area. The drain will be excavated to maintain a constant grade for the entire length. Where the drain terminates, channel and bank will converge at the natural surface. A vehicle crossing is to be constructed on this section as shown on Figure 1.

Overflow will occur around the northern end of the excavated drain. The overflow may be directed into a dam on Sims' property, with excess carried via field drainage across to the eastern drainage branch (refer to Section 2.3.6). The inclusion of drain 2 will reduce the amount of waterlogging on Sims' paddock on the corner of Wogilin Road South and Canal Road and, hence, reduce the erosion in Davenport's drain due to runoff from this paddock. For details of drain layout, refer to Figure 10.

2.2.5 Remnant Vegetation:

An agreement was reached at the Catchment Group meeting on 26 September 1994 that the existing natural drainage line through the remnant vegetation will be cleared of fallen debris to allow flow to pass more freely.

2.2.6 Drain Segment 3b:

Drain 3b will begin south of the remnant vegetation, downstream of a dam on Chadwick's property, following the natural drainage to join with the beginning of drain 8a. The bank will change sides twice along this section. At the northern most section spoil will be placed on the north-eastern side of the drain. The bank will merge with the dam wall and remain on the north- east for roughly the first 200 m, at which point it will be placed on the south east side to conform with an existing bank. The bank will continue on the south-east side of the drain for the next 1600 m. The existing channel passes through a dam. The new drain will be diverted to pass just south of the dam.

The bank will remain on the south-west of the drain until approximately 100 m south-east of the dam, and will allow for local runoff to enter the drain. The bank will then be pushed to the north-east side of the drain for the remaining length, allowing local runoff from the south-west to enter the drain. Two machinery and livestock crossings are to be constructed on this section, as shown in Figure 1. Crossings will have a minimal width of 15 m. The southern crossing will be stablized with gravel. For detail on changes in bank orientation refer to Figure 11.

2.2.7 Drain Segment 8a:

Drain 8a will require an upgrade of the existing channel to the design capacity. Spoil will be placed on the eastern side, as at present. The drain will diverge from the current line as it passes around the corner of Canal Road and Brown Road. The new curve in the drain will have a radius of curvature of 150 m as recommended (ASAE Standards, 1993). There are currently two far smaller radius, 90° bends in the drain at the corners of Brown Road and Oval Road, and of Brown Road and Canal Road.

An overflow path will be positioned along Canal Road just north of the point where the proposed drain diverges from the existing channel. The bank will be lowered and compacted at 0.20 m above natural surface for 10 m along the length of the drain allowing overflow onto Canal Road, during high flow events to prevent excessive inundation of land to the west of the drain. For detail on lowering of bank refer to Figure 12b.

Drain segment 8a has been divided into northern and southern sections, 8aN and 8aS, to reflect a significant difference in grade along this section.

2.2.8 Floodway 2:

The existing floodway across Brown Road should be retained at its existing configuration and stabilised.

2.2.9 Drain Segment 8b:

Drain 8b will begin roughly 500 m north of the end of the existing drain 8a and will extend south-west approximately 900 m, joining with the natural drainage line to Lake Dulbining. The length of drain in the CALM Reserve is 350 m.

For the last 350 m (approximately from the northern end of the CALM Reserve), the drain (drain segment 8bS) will gradually widen and become shallower as it curves south-west to merge with the natural drainage line. The bank and drain will converge at ground level at the edge of the natural drainage line. The bank will be placed on the eastern side of the drain.

The total channel width to remain permanently cleared of vegetation for drain segment 8bN is 9 m. The total channel width to remain cleared of vegetation on drain segment 8bS (at cross section A) will gradually increase along its length. 150 m north of the natural drainage line the total width will be 32 m. Further disturbance to vegetation will be caused by bank material (approximately 5 m width) and an initial machinery disturbance for access of approximately 7 m.

2.3 Eastern Drainage Branch

2.3.1 General

In runoff events greater than the 2 year ARI drain 1aE will carry overflow from Floodway 1 east along the table drain on the north side of South Wogolin Road to join with drain 1b.

Drain 1b carries runoff from Phil's catchment east along South Wogolin Road to join with runoff from Syd's catchment. Flow is then carried south along Davenport drain (4), then south-east towards a new drain running south to Brown Road (5) and then through the existing CALM Reserve drain (9) towards the eastern catchment drainage line which flows in a westerly direction through the Reserve to Dulbining Lake.

Drain 5 carries flow from Phil's and Syd's catchments back towards the natural drainage line. The drain has been designed to keep flow away from existing salt scalds, to the east of the drain.

2.3.2 Outlets of Keith's and Phil's Catchment:

The outlets of Keith's and Phil's catchment are both eroding where they enter the existing drain in the northern road verge of South Wogolin Road. To prevent further erosion the natural drainage line should be stablised for 50 to 100 m upstream of South Wogolin Road, at a non-erosive grade of 0.002.

2.3.3 Drain Section 1aE:

Drain 1aE should be desilted. It will carry overflow from Floodway 1 east along South Wogolin Road.

2.3.4 Drain Section 1b:

Drain 1b is the continuation of drain 1a from the point where flow from Phil's catchment reaches South Wogolin Road. An upgrade of the existing drain is required. The drain will continue east along South Wogolin Road with the spoil placed on the northern side of the drain, until approximately 20 m east of the existing culverts (existing culverts are approximately 60 m east of the intersection of South Wogolin Road and Canal Road). A Water Authority pipe crosses South Wogolin Road at Canal Road and should be lowered to prevent disruption to the pipe.

2.3.5 Floodway 3:

It is proposed that the existing culverts will be retained and a floodway constructed roughly 20 m east of the culverts to tie in with the existing drain carrying flow from Syd's catchment. The proposed floodway has been designed to carry flow from both Phil's and Syd's catchments. The existing drain carrying flow from Syd's catchment ends just north of South Wogolin Road, where a Water Authority water supply pipe runs east-west just north of the road. It is proposed to request the Authority to lower the pipe to allow the continuation of this drain to join with Floodway 3. A continuous drain should be excavated between the existing culverts and drain 4.

2.3.6 Drain Segment 4:

Maintenance of the existing drain 4 is required, particularly on the corner of South Wogolin Road and Canal Road, where silting has occurred. Overflow from Geoff Sims' property currently crosses Canal Road in several places. The flow has caused erosion of the road, road verges and drain 4 batters. Two small field drains will run west to east across Sims' property to two points on Canal Road at a distance of roughly 30 m and 1900 m south of South Wogolin Road. At these points small floodways and spur drains through the road verge will be constructed across Canal Road to allow flow to pass into drain 4. A Water Authority water supply pipe which runs down the west side of Canal Road may have to be located to prevent disruption of the pipe.

2.3.7 Drain Segment 5a:

Drain segment 5a is the continuation of drain 4 across to the east before the drain turns south. The path of drain segment 5a has been located to cross the property line between Davenport's and Chadwick's properties, west of monitoring bores on the southern side of the fence.

Natural surface contours suggest there may be a slight depression along segment 5a. A survey will be required along the pegged path to ensure a positive grade is maintained. (N.B. This depression has not been shown on Figure 4).

2.3.8 Drain Segment 5b:

This drain runs north-south from the end of section 5a to a floodway at Brown Road, with the bank on the eastern side of the drain. The drain will run to the east of a dam on the southern boundary of Chadwick's property, with overflow into the dam. Two machinery and livestock crossings are to be constructed on this section, as shown in Figure 1. Crossings will have a minimum width of 15 m. The southern crossing will be stablized with gravel.

An overflow route will be positioned on the top section of drain 5b to ensure that in high runoff events inundation occurs east of drain 5b rather than between the drain and Canal Road. The bank will be lowered and compacted to 0.20 m above natural surface for 10 m along the length of the drain. Low flow pipes are to be laid in the bank to convey "W" drain flows into the main drain, as shown on Figure 12a. For further details on overflow pathways refer to Section 5.

There is an increase in surface gradient for the last 100 m of drain 5b (Segment 5bS). The drain width could be marginally decreased for this southern section and maintain sufficient capacity. Velocity in the channel will remain less than 1 m/s.

If inundation of paddocks in this section becomes a problem in the future, the addition of a broad based bank approximately 50-100 m west of the excavated drain may be appropriate. Drain 5b should be fenced off with a buffer strip to allow revegetation.

2.3.9 Floodway 4:

A floodway should be constructed across Brown Road, connecting drain 5b to the existing CALM drain (9). The spoil will be placed on the eastern side of the floodway within the road reserve.

2.3.10 Drainage through Syd's Catchment:

We recommend that work in Syd's catchment be included as part of the West Toolibin Drainage Project.

Debris should be cleared from the natural drainage line through an area of remnant vegetation north of South Wogolin Road. The estimated cost of this work has been included under "bush raking" in Table 3.

2.4 Fencing

The replacement of fencelines is included as part of the drainage work but changes to fencelines are not covered in this report. Fences which run across the flow path will have lower wooden sections which tilt during periods of flow to allow debris to pass unhindered.

3.0 DESIGN FLOWS

The Water Authority's Northern Arthur River gauging station (609010) is located on the channel between Dulbining Lake and Lake Toolibin on the Wickepin to Harrismith Road. Since records commenced in 1981, the highest flow of 59 m^3/s was on 29 June 1983 and the second highest was 29 m^3/s on 30 January 1990. During 1983 approximately 17 Mm^3 (million cubic metres) flowed past the gauging station, effectively flushing the 3.5 Mm^3 volume of Lake Toolibin about 5 times. Lake Toolibin next overflowed slightly in the winter of 1990 and almost filled to overflowing in 1992. In between these times water in Lake Toolibin was generally decreasing in volume, with some winter inflows.

Figure 13 shows a Flood Frequency Analysis of annual maximum instantaneous peak flows at the gauging station. Two data points are identified corresponding to peak flows in 1983, and 1990.

Figure 13 also shows the Index Flood Method (Australian Rainfall & Runoff, I.E. Aust., 1987 - referred to here as AR&R) applied to the portion of the catchment (356 km^2) which contributes flow to the gauging station. There is reasonable agreement between the two methods, especially for Average Recurrence Interval (ARI) greater than 5 years. Using the Index Flood method, the 5 year ARI peak flow is estimated to be 20 m^3/s and the 2 year ARI flow is 9 m^3/s.

Values obtained from the Index Flood Method have been adjusted to reflect a local knowledge that, for a given storm event, roughly 70% of flow from the catchment comes from the western catchments, which have an area of about 57% of the total area contributing to the gauging station. The drains have been sized to carry a 2 year ARI flow at all sections of the drains.

Previous preliminary design of drains for the Toolibin Flats (Negus, 1990) was based on the 5 year ARI peak flows estimated, using the Rational Method (as described in AR&R), an alternative method to the Index Flood Method. The Rational Method generally over predicts relative to the Index Flood Method and the good correspondence shown on Figure 9 suggests that the Index Flood Method is more appropriate for this catchment. The Negus drain designs were based on the 5 year ARI peak flow, whereas we consider that a lesser flow rate should be designed for, allowing overbank flow of perhaps several days duration during a 5 year ARI peak flow. There is some evidence that crops and pastures can tolerate such durations with an acceptable reduction in yield (Jim Davies & Associates and Muir Environmental, 1994b). Smaller channels are also easier to maintain and are considered more appropriate given the ephemeral nature of runoff from the Toolibin Flats. It follows that the drain dimensions proposed are smaller than those proposed by Negus. The individual drain design flows for each drain segment for 2, 5, and 10 year ARI are presented in Table 1.

TABLE 1: DRAIN DESIGN FLOWS

Drain Segment	Contributing Area (km^2)	Q_2 (m^3/s)	Q_5 (m^3/s)	Q_{10} (m^3/s)
Gauging Station	356	9.27	19.31	35.53
Western Flats	202	7.70	16.04	29.51
Floodway 1	16.75	2.11	4.40	8.09
2	16.75	2.11	4.40	8.09
3b	85.88	4.94	10.29	18.93
8aN	85.88	4.94	10.29	18.93.
8aS	91.74	5.11	10.65	19.59
8bN &S	91.74	5.11	10.65	19.59
1aE	To	carry	over	flow
1b	18.22	2.20	4.59	8.45
Floodway 3	18.22	2.20	4.59	8.45
4	52.10	3.81	7.93	14.59
5a	52.10	3.81	7.93	14.59
5bN	52.10	3.81	7.93	14.59
5bS	52.10	3.81	7.93	14.59
9	95.28	5.21	10.86	19.98
Floodway 4	95.28	5.21	10.86	19.98

Example of Design Flow Calculation

1. Flow from Western Flats

Contributing Area to Gauging Station, A(T) = 356 km^2
Contributing Area to Western Flats, A(F) = 202 km^2 (57% of total area).

However, the Western Flats contributes 70% of flow; hence 'effective area' is 70% of total. Therefore flow from the flats:

$$Q(F) = Q(T) \times \left[\frac{A(F)}{A(T)}\right]^{0.52}$$

$$= Q(T) \times (0.7)^{0.52}$$

Where Q(F) is flow from Western Flats.
Q(T) is flow at gauging station, calculated by the Index Method (described in Section 4.0).
A(F) is contributing area to Western Flats.
A(T) is contributing area to Gauging Station.

2. Design Flows for Drainage Segments

$$Q(I) = Q(F) \times \left[\frac{A(I)}{A(F)}\right]^{0.52}$$

Where Q(I) is flow from drain segment.
Q(F) is flow from Western Flats.
A(I) is contributing area to drain segment.
A(F) is contributing area to Western Flats.

Example: Drain 3, 2 year ARI

$$I = 3$$
$$Q(T) = 9.27\ m^3/s$$
$$Q(F) = 9.27 \times (0.7)^{0.52}$$
$$= 7.7\ m^3/s$$
$$A(F) = 202\ km^2$$
$$A(3) = 85.9\ km^2$$
$$Q(3) = 7.7 \times \left(\frac{85.9}{202}\right)^{0.52}$$
$$= 4.94\ m^3/s$$

4.0 DRAIN AND FLOODWAY DESIGN

The design of drains is based on the Department of Agriculture's recommendations, with minor modifications (Department of Agriculture, 1989).

Drain sizes have been designed using the Manning Equation.

$$Q = \frac{AR^{0.67}S^{0.5}}{n}$$

Where	A	=	area of cross section of flow (m^2)
	R	=	hydraulic radius (m)
	S	=	hydraulic slope
	n	=	Manning roughness coefficient
	Q	=	flow (m^3/s)

This equation applies to uniform flow, for which the hydraulic friction slope equals the channel bed slope, the flow is constant with time and the channel shape is constant. The equation allows the required cross sectional area for a given channel grade, flow rate (calculated as described in Section 3.0) and velocity to be determined.

The assumptions inherent in the Mannings formula are considered reasonable for drain design on Toolibin Flats.

Design depths, widths and side slopes are presented in Table 2, and shown diagramatically in Figures 5 to 8. To prevent soil erosion, all drain segments have been designed for velocities of less than 1 m/s, as recommended for clay loam soils with negligible grass cover (WADA, 1989).

TABLE 2: DRAIN DESIGN USING MANNING'S EQUATION

Drain	Design Discharge (m^3/s)	Slope %	bottom width (m)	depth (m)	Side Z1	Slopes Z2	Top Width (m)	A(area) (m^2)	P(wetted perimeter) (m)	A/P (m)	R^2/3	V (m/s)	Capacity (m^3/s)
1aW	2.11	0.23	4.5	0.4	3	3	6.9	2.28	7.03	0.32	0.47	0.91	2.08
floodway1	2.11	0.10	5.0	0.3	50	50	35.0	6.00	35.01	0.17	0.31	0.39	2.34
2	2.11	0.17	5.0	0.4	10	3	10.2	3.04	10.28	0.30	0.44	0.73	2.20
3b	4.93	0.17	3.0	0.7	10	3	12.1	5.29	12.25	0.43	0.57	0.93	4.90
8aN	4.93	0.09	5.5	0.7	10	3	14.6	7.04	14.75	0.48	0.61	0.71	5.01
8aS	5.10	0.15	4.0	0.7	10	3	13.1	5.99	13.25	0.45	0.59	0.90	5.40
8bN	5.10	0.15	7.0	0.6	5	3	11.8	5.64	11.96	0.47	0.61	0.94	5.29
8bS	5.10	0.1	30.0	0.3	5	3	32.4	9.36	32.48	0.29	0.44	0.55	5.17
1aE	1.24	0.23	2.5	0.4	3	3	4.9	1.48	5.03	0.29	0.44	0.85	1.26
1b	2.20	0.12	3.0	0.6	3	3	6.6	2.88	6.79	0.42	0.56	0.78	2.25
floodway3	3.81	0.10	14.5	0.3	50	50	44.5	8.85	44.51	0.20	0.34	0.43	3.81
4	3.81	0.09	4.0	0.7	12	2	13.8	6.23	13.99	0.45	0.58	0.70	4.36
5a	3.81	0.20	5.5	0.5	10	3	12.0	4.38	12.11	0.36	0.51	0.91	3.97
5bN	3.81	0.05	12.5	0.5	10	3	19.0	7.88	19.11	0.41	0.55	0.49	3.83
5bS	3.81	0.09	9.0	0.5	10	3	15.5	6.13	15.61	0.39	0.54	0.64	3.92
floodway4	5.21	0.10	7.5	0.4	50	50	47.5	11.00	47.51	0.23	0.38	0.48	5.25

Notes:

1. Topographic data was not available to determine the slope for drain segment 1aW. A value equal to that of drain 1aE has been assumed.
2. The depth used in design of drain segment 2 is an average depth over the length of the drain. The maximum depth of the drain will be approximately 0.7 m.
3. Drain 8bS will gradually widen and become more shallow from north to south. The channel bottom will meet natural surface at the south end where it reaches the natural drainage line. Dimensions shown above are at a point 150 m north of the natural drainage line and are not to be applied over the entire length of the drain.

5.0 OVERFLOW PATHWAYS

When flows occur above drain capacity water will generally break out of the channel on the side not protected by the bank formed by spoil material.

All banks have been placed on the downslope side of drains. This allows overflows to pass back into the drains once the high flows have subsided.

There will be defined locations where overflows will not directly return to the drain as follows:

1. Floodway 1: Overflow will occur east into drain 1aE and continue east along South Wogolin Road to enter the eastern drainage branch.

2. Drain Segment 2: Overflow will occur around the northern end of the drain and into a farm dam. Once the dam is full, overflow will continue east via field drains to enter the eastern drainage branch.

3. Drain Segment 8a: An overflow will be created by lowering of the bank, as described in Section 2.2.7. Overflow will pass onto Canal Road, across Brown Road and into the CALM Reserve where it will make its way down to the natural drainage line to Lake Dulbining.

4. Drain Segment 5b: An overflow area will be created by lowering of the bank, as described in Section 2.3.8 The break in the bank will be located to allow field drainage from an existing W-drain to enter the main drain in low flows. In high flows water will back up into the W-drain until the water level in the main drain subsides, after which overflow will return to the main drain. Some overflow may also run east across the paddock to the natural drainage line

Overflow paths are presented in Figure 14.

6.0 IMPACT OF DRAINS ON LAKE TOOLIBIN AND CALM RESERVES

The Lake Toolibin Recovery Plan stated that it was difficult to assess whether improved drainage on Toolibin Flats would be beneficial or detrimental to the water quality and vegetation of Lake Toolibin Reserve. This opinion is still valid.

Since preparation of the Recovery Plan water quality data for Lake Toolibin indicate that the salinity is increasing and that the total salt load has virtually doubled from 40 tonnes over the gauged period from 1981 to 1990 to approximately 80 tonnes as from the last filling in 1992. The Lake is now progressively emptying by evaporation with consequent concentration of dissolved salts until flushing during the next overflow period.

Given the deterioration of the lake water quality and imminent deterioration of lakeside vegetation, CALM has decided that drainage of the Toolibin Flats will be implemented as opposed to the 'do nothing option'. The drainage system will be part of an integrated catchment project comprising field drains (refer to Walsh 1994), revegetation programs by landholders and monitoring programs to detail the impact on Toolibin Lake and CALM Reserve.

In general we consider that the improved drainage system will result in increased volumes of water entering Lake Toolibin. The drainage has been designed to optimize fresh flow into the Lake. The drainage will minimize the area of salt-affected land receiving runoff from upper catchment areas and thereby reduce the potential salt load into the Lake. It will also reduce the potential area and duration of inundation of agricultural land and thereby reduce the mobilization of nutrients from crop and livestock production. In large events the system should assist with the flushing of Lake Toolibin.

Drainage of Toolibin Flats is considered necessary to the rehabilitation of the Flats, with reduced waterlogging on the Flats allowing establishment of perennial vegetation and annual crops and pastures and thereby increasing the transpiration component. Without an integrated drainage scheme, as proposed herein, evapotranspiration on the Flats during winter is reduced and recharge enhanced, which exacerbates the salinity problem for both the Toolibin Flats and Lake Toolibin. We believe that drainage is part of a solution to the problems of Lake Toolibin rather than a cause of them.

The relative magnitudes of the water balance components is unknown, hence a monitoring program is critical in achieving an effective, ongoing management strategy for Toolibin Lake and CALM Reserves. We recommend that the monitoring data collected be reviewed annually with a specific intention of assessing the impact of the drains on Lake Toolibin. These data should be analysed in conjunction with the water quality data of the Lake and at the gauging station on the Northern Arthur River. It is presumed that the Water Authority will continue to operate these gauging stations as a community service obligation to assist with the State's responsibility with respect to Lake Toolibin.

Within the CALM Reserve there will be areas of localised benefit and areas placed under increased pressure from waterlogging. Drain banks will protect large areas from waterlogging while drain outlets will create localised areas of increased inundation.

Drain 8bS will require the removal of vegetation in the CALM Reserve. It is proposed that drain 8bS widen as channel depth decreases to meet with natural surface, to maintain flow capacity. However, flow conditions in drain 8bS may be governed by the water level in the natural drainage line to Lake Dulbining rather than channel dimensions. Consequently the proposed widening of drain 8bS as it approaches the natural drainage line could be altered to a constant width channel with negligible loss to flow capacity. This approach would create less disturbance to vegetation.

7.0 DRAIN MAINTENANCE

There is some evidence of localised erosion in the existing drainage lines on Toolibin Flats. Examples occur where Keith's catchment flows on the northern side of South Wogolin Road, where Keith's catchment joins the system. There is also some erosion of the western batter of Davenport's drain where flow occurs across Canal Road into the drain. Within Davenport's drain itself siltation is occurring, leading to loss of flow capacity. The source of this material appears to be the upstream sections of Davenport's drain and associated banks rather than erosion of paddocks.

There is therefore a need for maintenance of the existing system.

The proposed drainage system will also require maintenance to retain integrity of the system. The degree of maintenance required will depend, to some extent, on the rainfall and runoff severity in individual years and only average maintenance requirements are discussed here.

It should be noted that the drains have been designed for particular flow rates. The actual flows which occur in these drains may be greater or less than estimated in this report, due to the uncertainty in estimating runoff rates. For those drains where the actual flows exceed the estimated flows it is likely that more maintenance will be required than in those drains where actual flows are less than those estimated.

The following drainage requirements are extracted from Department of Agriculture recommendations (Department of Agriculture, 1989).

Grade banks should be maintained at their design height along their entire length, because overtopping at any low point may bridge the bank and cause serious erosion downslope. Therefore it is important that any low points that may develop at stock or vehicle crossings should be checked at least once a year and built up again as required. Because the drains have been designed to flow full, at natural surface during the design flow the crest of the spoil bank is not as crucial as with grader banks. Primary maintenance requirement is to ensure the capacity is maintained by periodic desilting. If drain sections are found to be actively eroding then this may be allowed to continue to a hard base or attempts made to stabilise this section with vegetation to decrease flow velocities. Alternatively a drop structure may be necessary. We believe that it would generally be best to allow the drain to scour naturally to a hard indurated base level.

Drain maintenance requirements should be determined annually by the catchment group in consultation with the Department of Agriculture. Any maintenance recommended should be performed on individual properties as a responsibility of the landowner.

8.0 MONITORING OF DRAIN PERFORMANCE

8.1 Objectives of Monitoring of Drains

(i) To assess the impact of the drains on Lake Toolibin in terms of water quantity and water quality.

(ii) To assess the adequacy of the drains to alleviate inundation, waterlogging and salinity of the Toolibin Flats.

(iii) To assess the need to modify the drains to alter the impact on Lake Toolibin or the Toolibin Flats.

(iv) To provide information to further develop management plans for Lake Toolibin and the associated lake system.

8.2 Parameters to be Monitored

(i) Instantaneous flow in the drains to allow daily peak flow and daily flow volume to be determined.

(ii) Total dissolved solids (TDS) at appropriate intervals to allow estimation of annual salt load.

(iii) Total phosphorus (TP) at appropriate intervals to allow estimation of annual phosphorus load.

(iv) Total nitrogen (TN) at appropriate intervals to allow estimation of annual nitrogen load).

Instantaneous flow can be estimated from a record of water level (stage) in a drain using a capacitance probe or hydrostatic pressure probe, combined with a stage discharge rating curve. There will be no supercritical controls along the drain, either natural or artificial, but a rating curve can be derived of sufficient accuracy (say +/- 20%) by discharge measurement using a wading current meter set.

TDS can be measured with sufficient accuracy (say +/- 5%) using an electrical conductivity (EC) meter as operated by the Department of Agriculture at Narrogin.

TP and TN require laboratory analysis using standard methods.

8.3 Monitoring Locations

To avoid excessive backwater effects on rating curves from the water level in Lake Toolibin, the suggested two monitoring locations are shown in Figure 1; one on the West Drainage Branch and one on the East Drainage Branch.

8.4 Estimated Cost of Proposed Monitoring

8.4.1 Flow Monitoring:

8.4.1.1 Capital Costs: (NB Based on capacitance probe equipment from Unidata)

Purchase of equipment, including sensors (0.5m long), data loggers, cabling, software, installation brackets, etc. and labour for two locations	$7,000

8.4.1.2 Operating Costs: (NB Cost per year)

Allow 10 site visits per year, comprising 3 from Perth, 7 from Narrogin.
Assume current meter set already owned by WADA.

Labour Costs:	(a) 3 visits x 10 hrs at $50/hr	$1,500
	(b) 7 visits x 4 hrs x at $50/hr	$1,400
	Sub Total	$2,900/year
Disbursements:	(a) Travel 3 visits x 500 kms at $0.50/km	$750
	(b) Travel 7 visits x 50 kms at $0.50/km	$175
	Sub Total	$925
	Total Operating Costs	$3,825/year

8.4.2 TDS Monitoring:

8.4.2.1 Capital Costs:

Negligible.

8.4.2.2 Operating Costs:

Assuming samples taken manually by landholders at no cost to WADA/CALM with additional samples taken on the 10 monitoring visits referred to in 5.4.1.2 above, costs are included in above figures.

8.4.3 TP & TN Monitoring:

8.4.3.1 Capital Costs:

Negligible.

8.4.3.2 Operating Costs:

Assuming samples taken manually by landholders at no cost to WADA/CALM with additional samples taken on the 10 monitoring visits referred to in 5.4.1.2 above, costs are included in above figures.

Analysis costs, say 10 samples (50TP, 50TN), at $10/sample (performed by Murdoch University)	$1,000/year.
Total Operating Costs per annum	$1,000

Therefore for proposed monitoring programme:

total Capital Costs	$7,000
total Operating Costs	$4,825/year

Above costs exclude data analysis and reporting. Allow say $5,000/year for these items.

9.0 COST ESTIMATES - DRAIN CONSTRUCTION

To estimate construction cost, each segment was assessed to determine the work required; i.e., whether a new drain, an upgraded drain or maintenance on existing drains was required to ensure the drain has the capacity to carry the design flows. An estimate of cost per unit length of drain for each category was made. Costs of floodways (with gravel surface), machinery and livestock crossings, signs on floodways and fencing required were included; however, W-drains (field drainage), monitoring structures and cost of supervision of earthwork installation were not included. A summary table of estimated cost is presented in Table 3.

Cost estimates should be used as a guide when assessing proposals from earth moving contractors.

TABLE 3

ESTIMATED COSTS

1. Cost of Drains

Drain	Length	Maintenance (grader)		Channel Upgrade (bulldozer)		New Drain (bulldozer)		Gravel on crossings	Total
	(km)	($/km)	cost($)	($/km)	cost($)	($/km)	cost($)	cost($)	($)
1aW	0.4			1000	$400				$400
1aE	1.27	500	$635						$635
1b	0.72			1000	$720				$720
2	1.1					2700	$2,970		$2,970
3b	2.2					2700	$5,940	$400	$6,340
4	2.3	500	$1,150						$1,150
5a	0.94					2700	$2,538		$2,538
5b	2.31					2700	$6,237	$400	$6,637
8a	1.8			2000	$3,600				$3,600
8b	0.9					2700	$2,430		$2,430
Totals		1000	$1,785	3000	$4,320	13500	$20,115	$800	**$27,420**

2. Floodways

Floodway	Bulldozer work	gravel	road signs ($90 ea.)	bitumen	Totals
1. Sth Wogolin Rd (segment 2)	$1,000	$600	$180	$500	$2,280
2. Brown Rd (segment 8a)		$600			$600
3. Sth Wogolin Rd (segments 1b-4)	$1,000	$600	$180	$500	$2,280
4. Brown Rd (segments 5b-9)	$1,000	$600	$90		$1,690
Totals	$3,000	$2,400	$450	$1,000	**$6,850**

2. Additional Costs

lowering of WAWA pipeline	$1,000
fencing	$5,000
grader work (small banks and general clean up)	$3,500
bush raking (through remnant vegetation)	$1,000
Total	**$10,500**

<u>TOTAL COST ESTIMATE =</u> **<u>$44,770</u>**

10.0 REFERENCES

Jim Davies & Associates (1994a) Toolibin Flats Drainage Options. Department of Conservation and Land Management

Jim Davies & Associates in association with Muir Environmental (1994b) Review of Rural Drainage Maintenance Practices with Special Regard to Nutrient Reduction. Water Authority of Western Australia.

Institution of Engineers, Australia (1987) Australian Rainfall and Runoff - A Guide to Flood Estimation.

Negus, T. (1990) Toolibin Flats Surface Drainage Network Preliminary Design Proposals.

ASAE Standards (1993) 40th Edition Standards Engineering Practices Data. American Society of Agricultural Engineers.

Western Australian Department of Agriculture (1989) Soil Conservation - Earthworks Design Manual.

Walsh, J. (1994) Surface Water control & Drainage Scheme: Lake Toolibin Sub-Catchment. Western Australian Department of Agriculture, Narrogin.

FIGURES

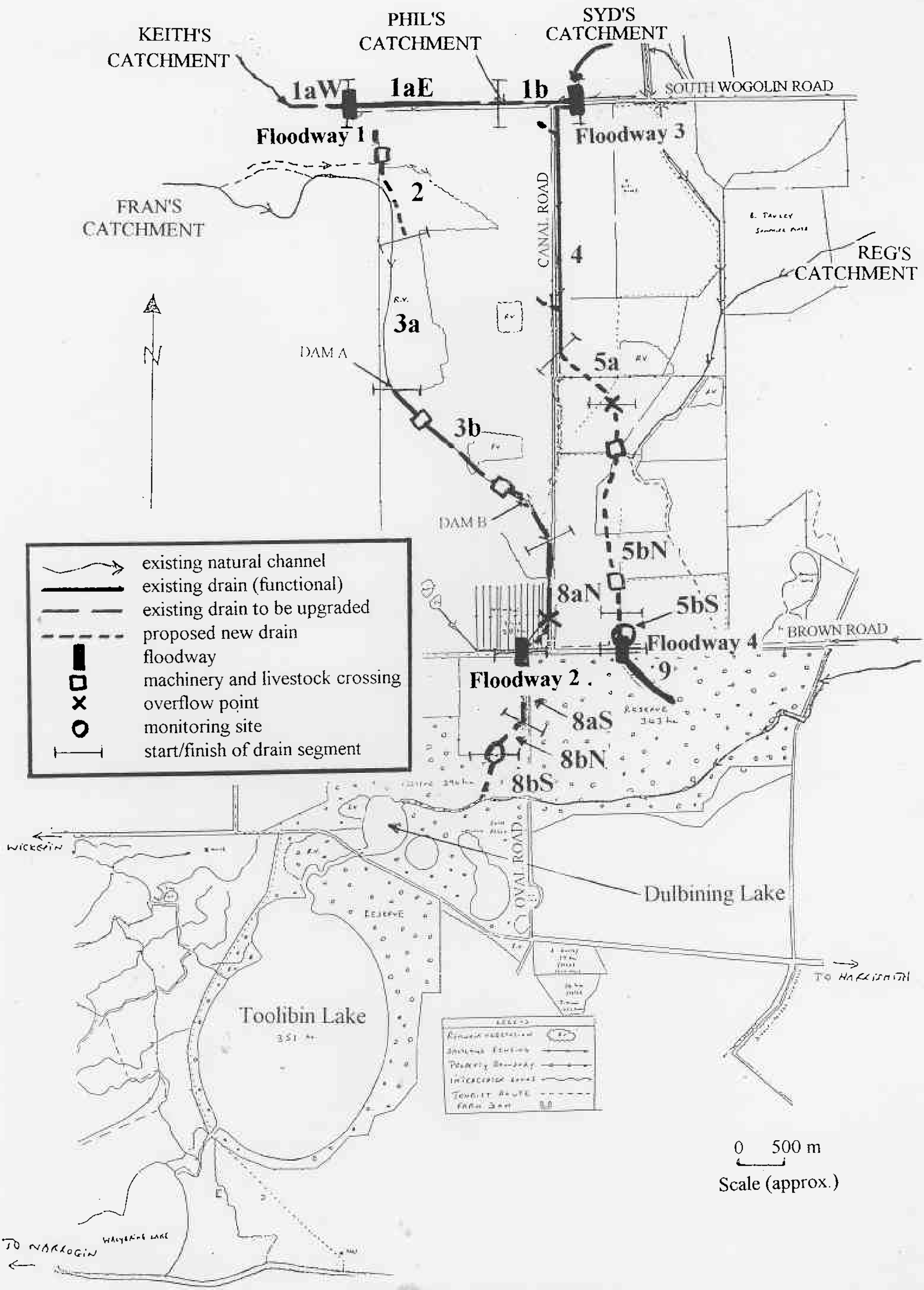


FIGURE 1: LOCATION MAP

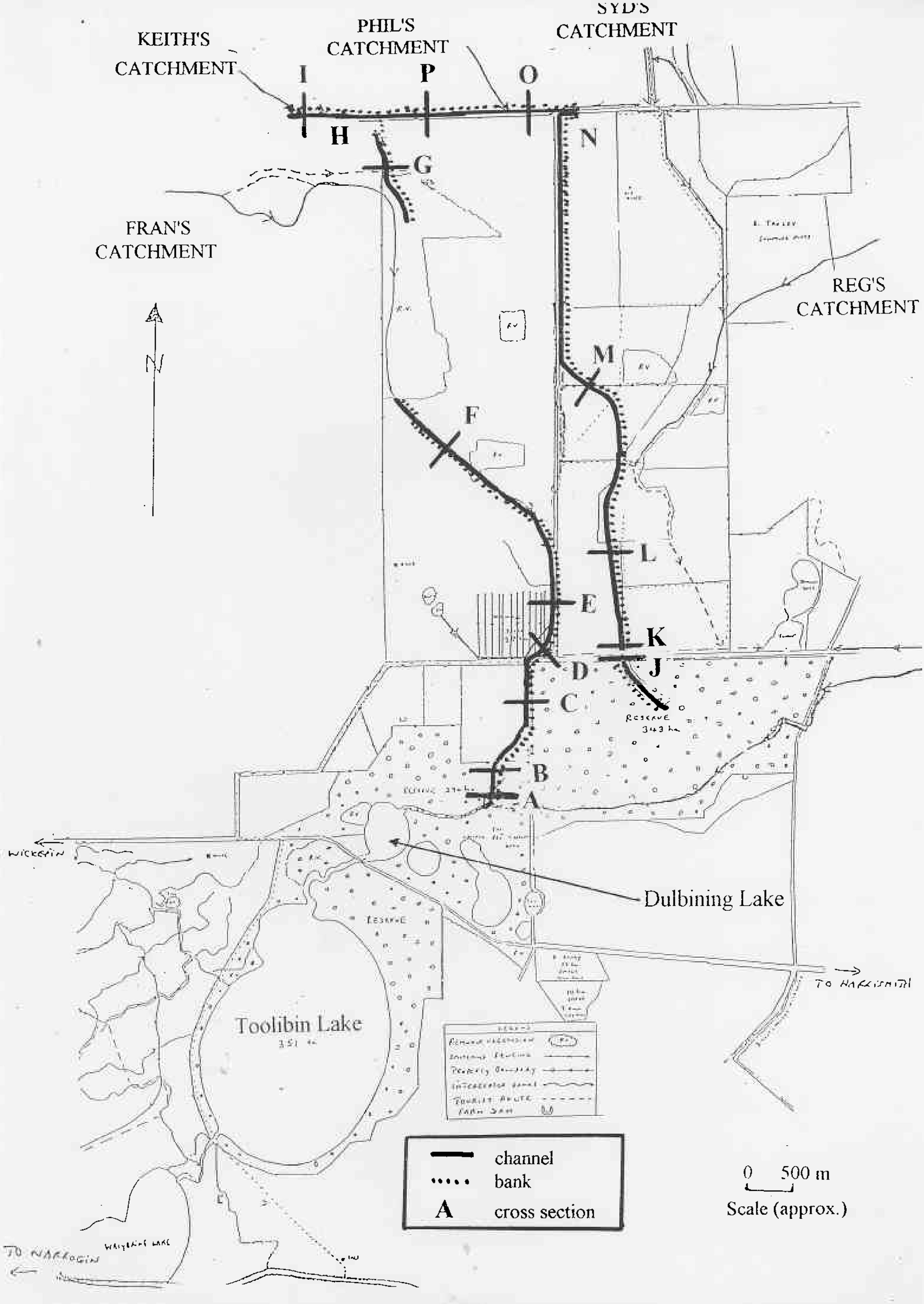


FIGURE 2: BANK ORIENTATION AND CROSS SECTION LOCATIONS

Long section along drain 1-2-3-8

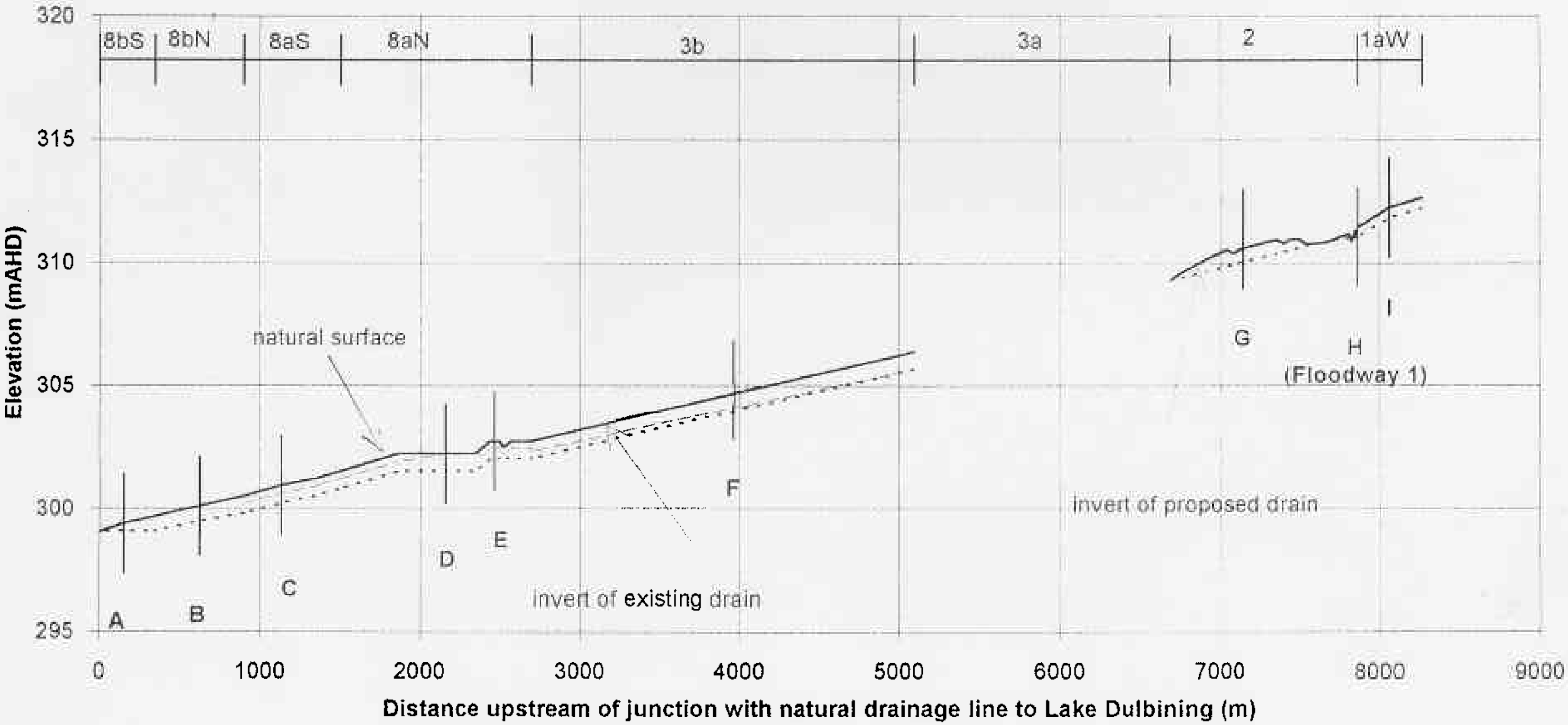


FIGURE 3: LONG SECTION - WESTERN DRAINAGE BRANCH

EAST_PRO.XLS Chart 1

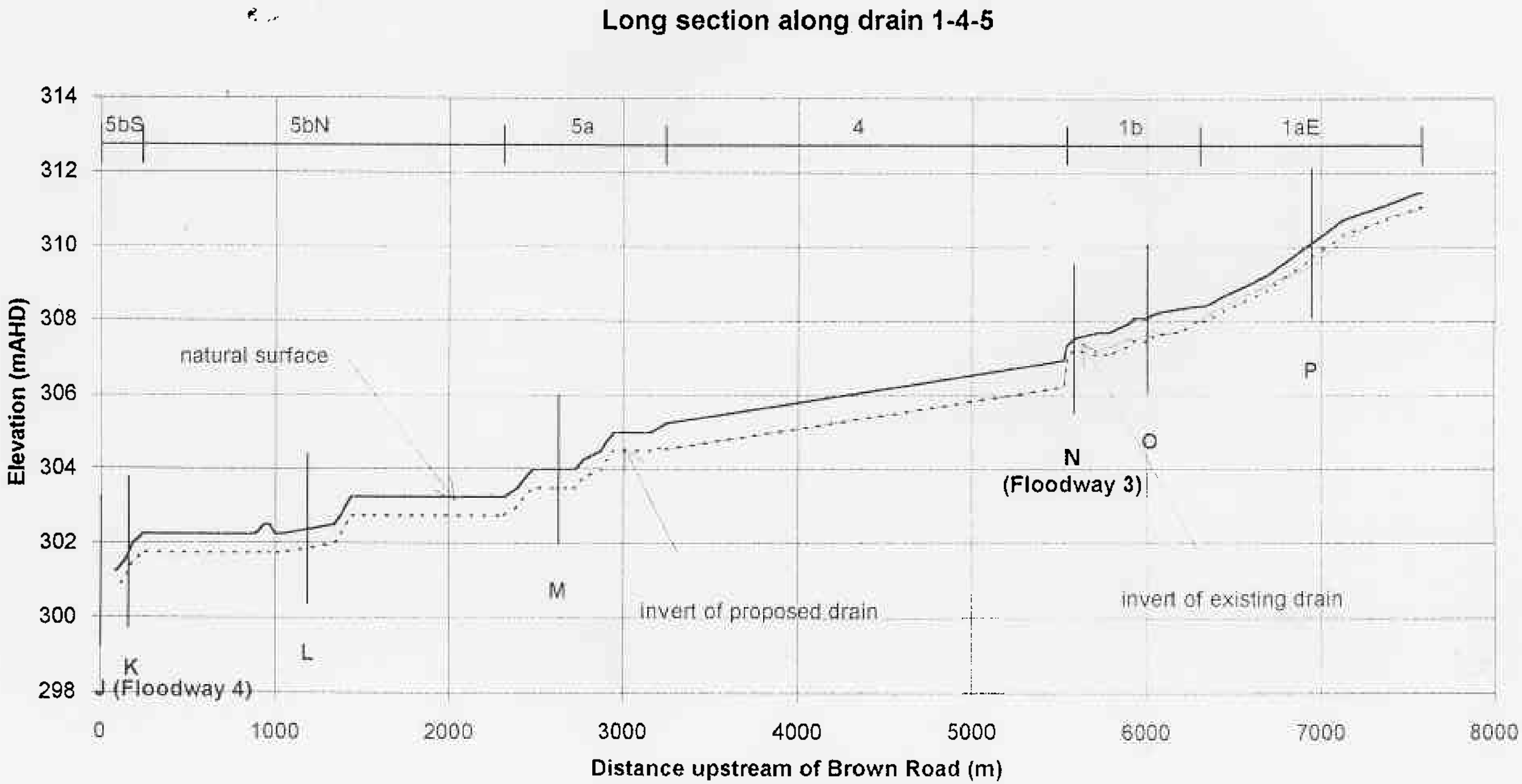


FIGURE 4: LONG SECTION - EASTERN DRAINAGE BRANCH

KEY TO FIGURES 5 TO 9

	**Design Water Level (2 Year Flow)**
	**Proposed Drain Cross Section**
	**Existing Drain Cross Section**

PROPOSED DRAIN DETAILS

A	**Cross Section Area to Design Water Level (m^2)**
b	**Bed Width (m)**
d	**Depth (m)**
s	**Side Slope of Batter**

Note:

Detailed design of floodway is to be approved by the Shire of Wickepin. Preliminary designs only are indicated.

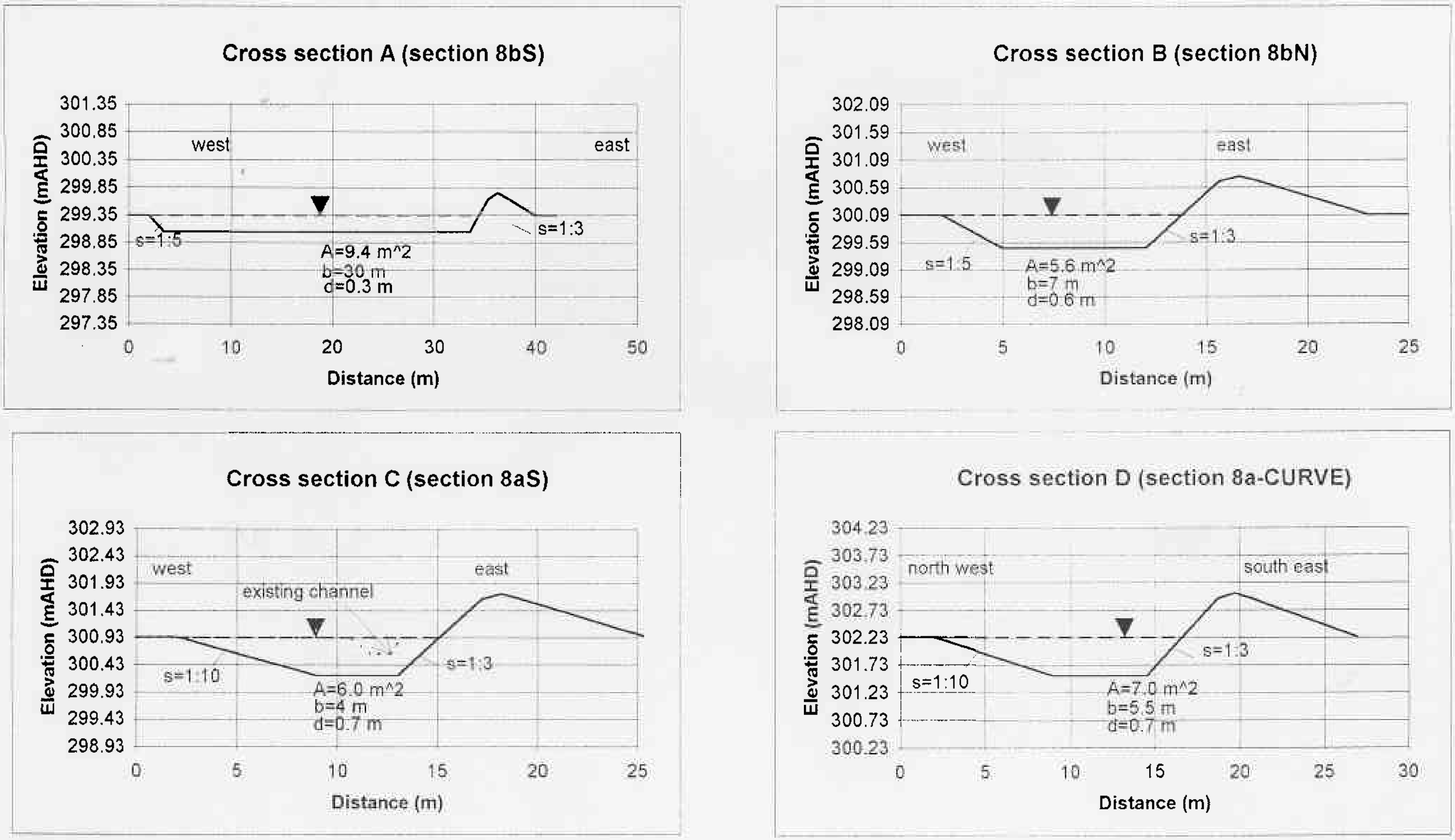


FIGURE 5: CROSS SECTIONS A, B, C & D

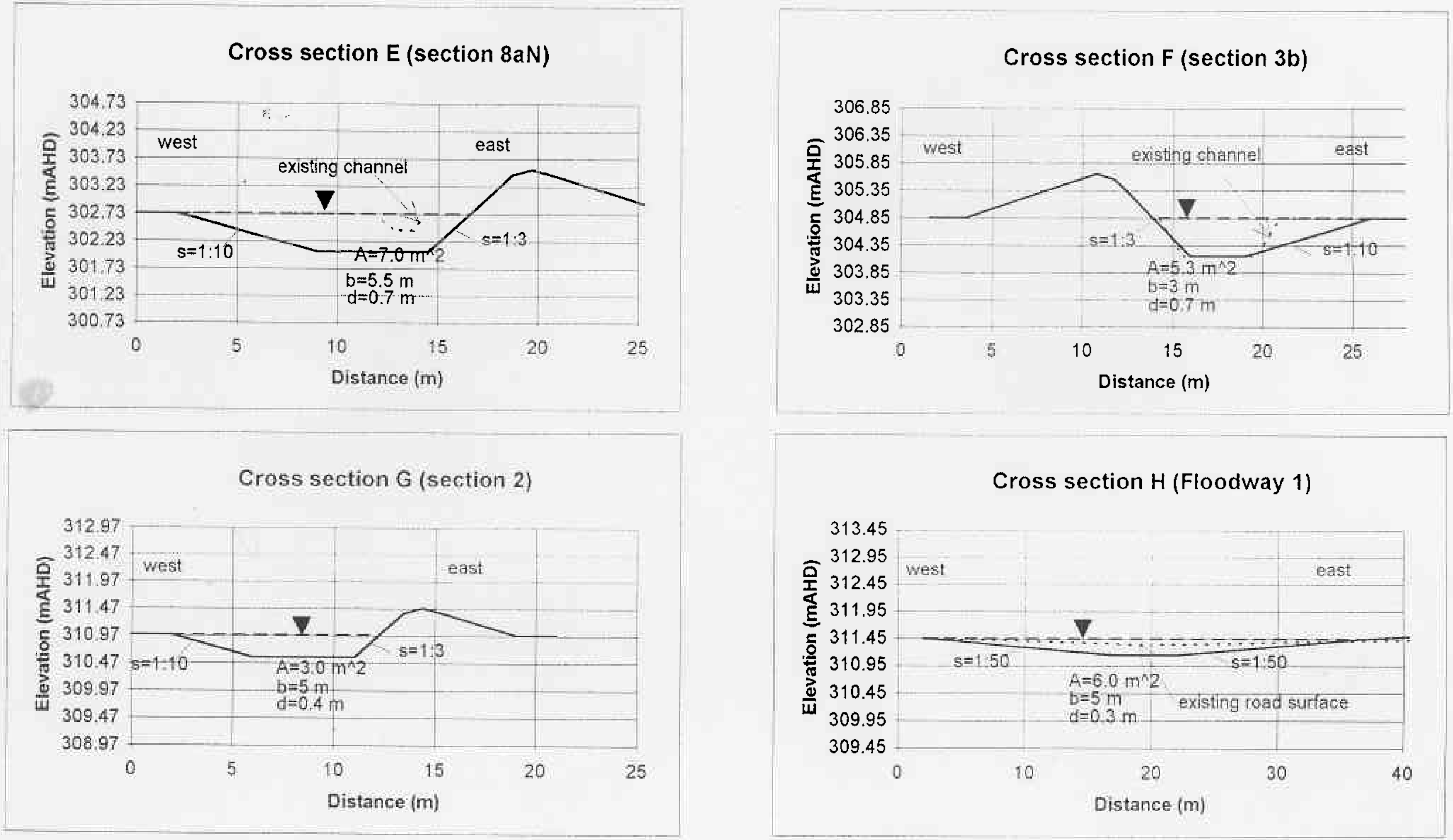


FIGURE 6: CROSS SECTIONS E, F, G & H (FLOODWAY 1)

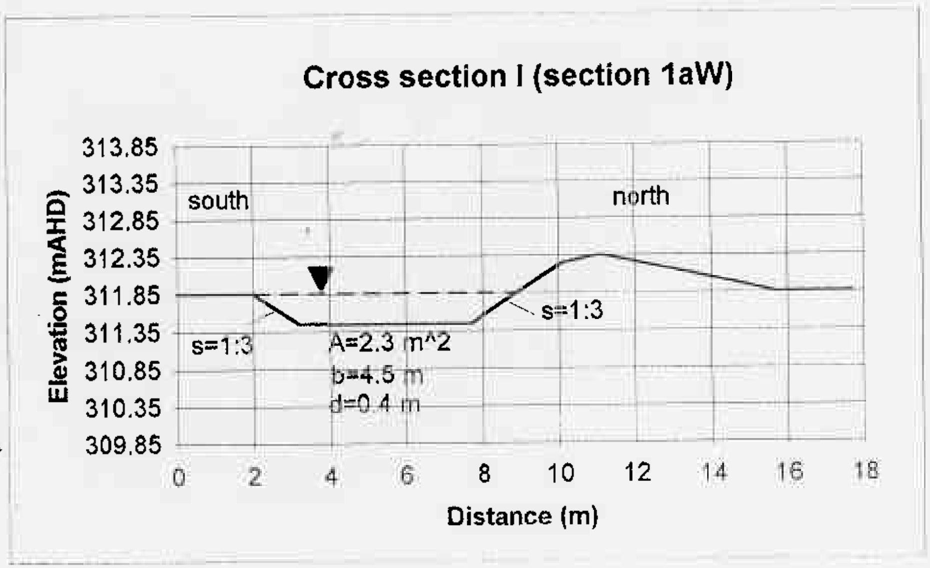


FIGURE 7: CROSS SECTION I

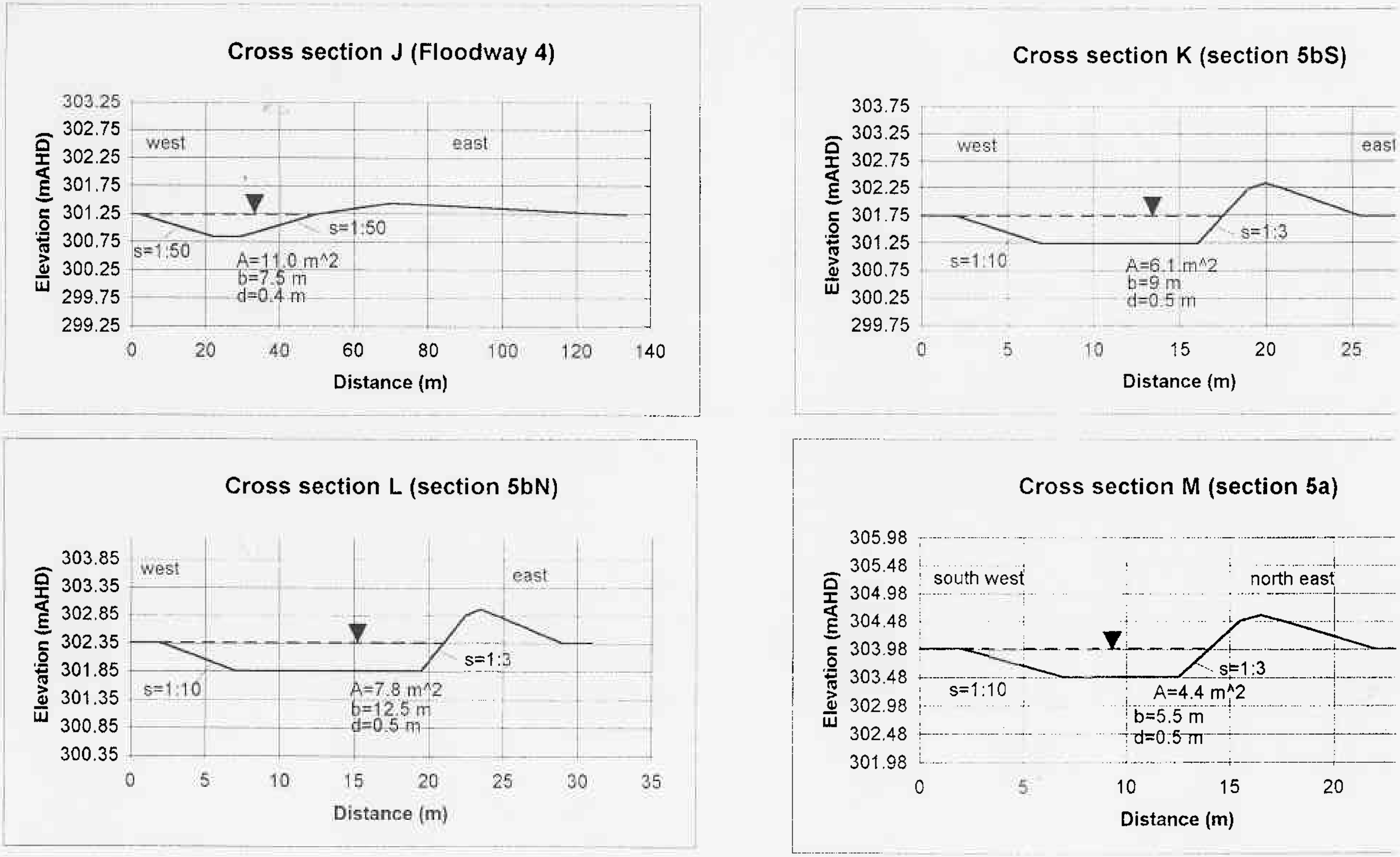
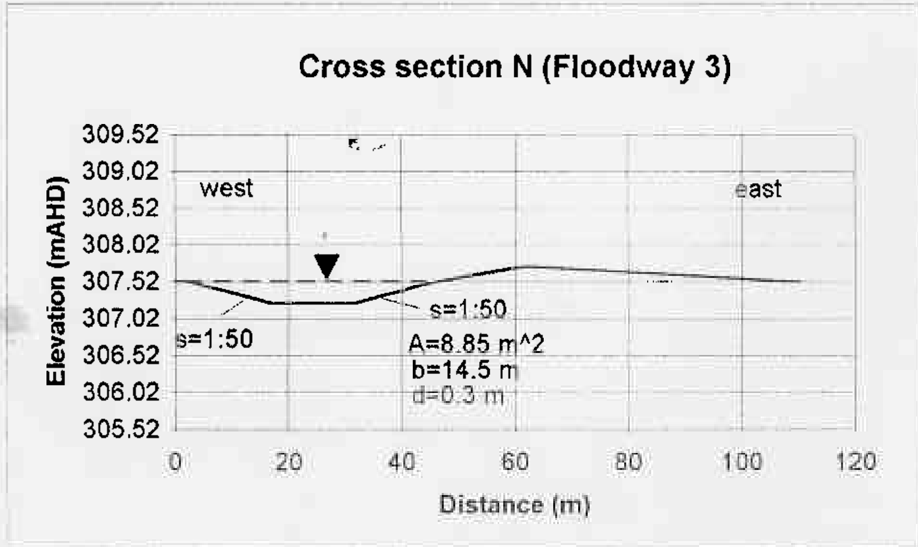
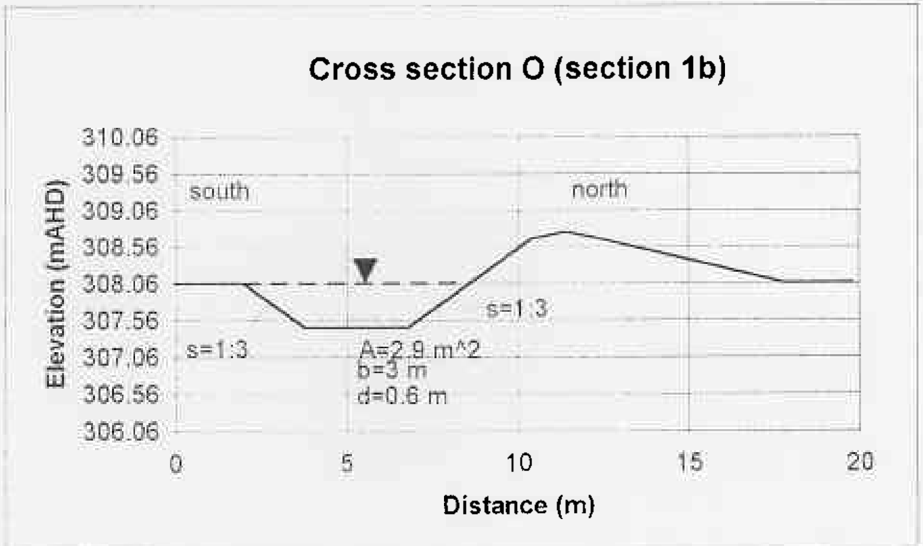


FIGURE 8: CROSS SECTIONS J (FLOODWAY 4), K, L & M





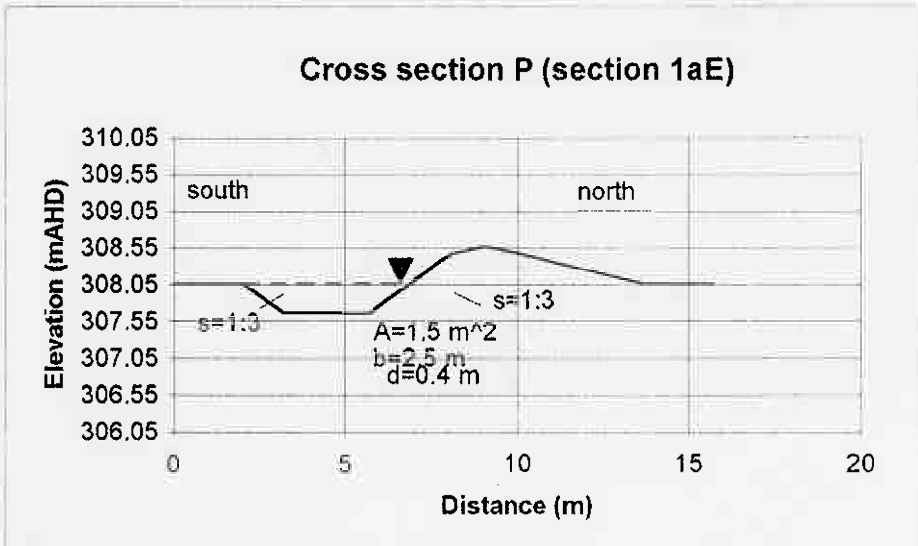


FIGURE 9: CROSS SECTIONS N (FLOODWAY 3), O & P

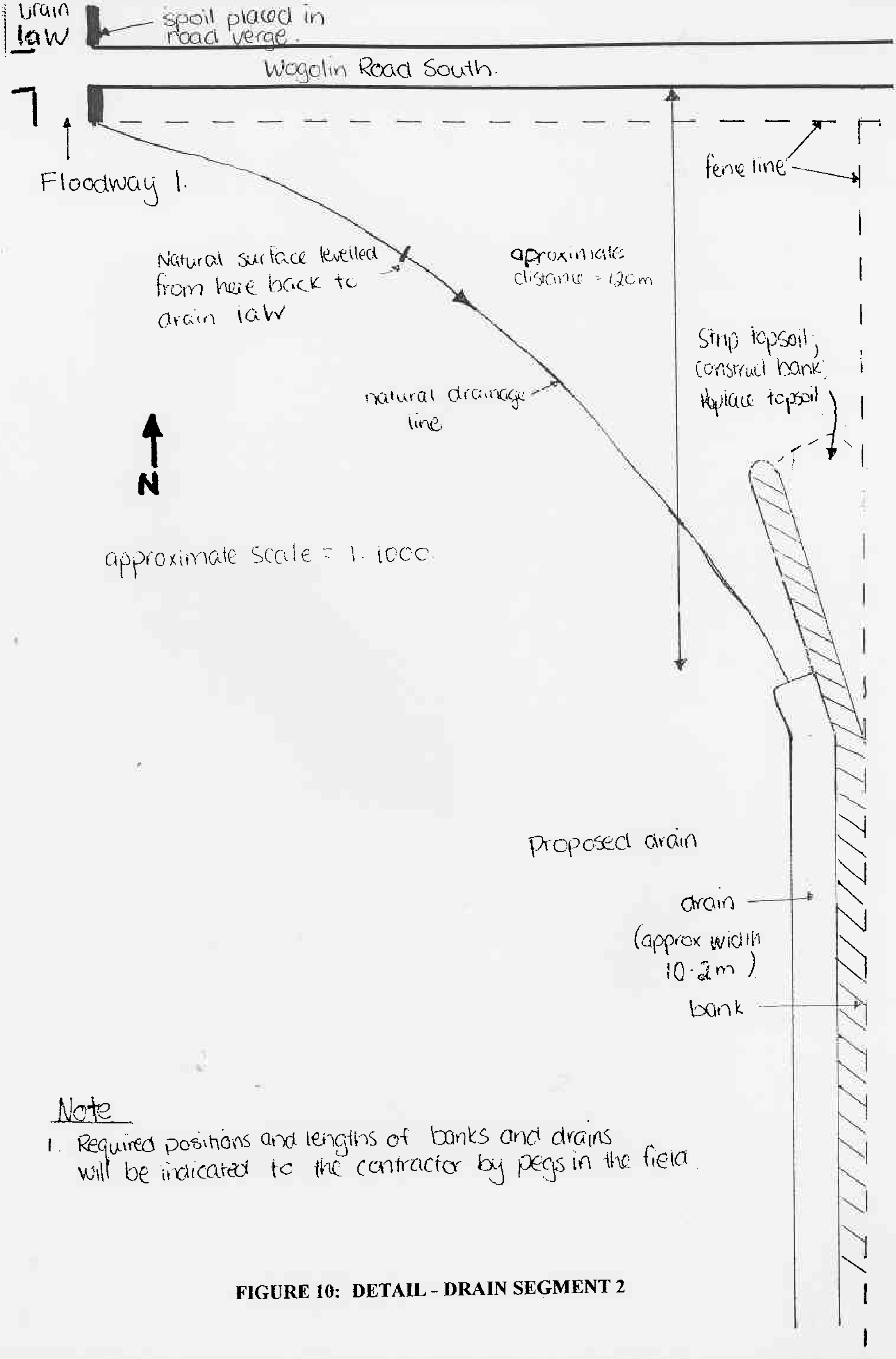
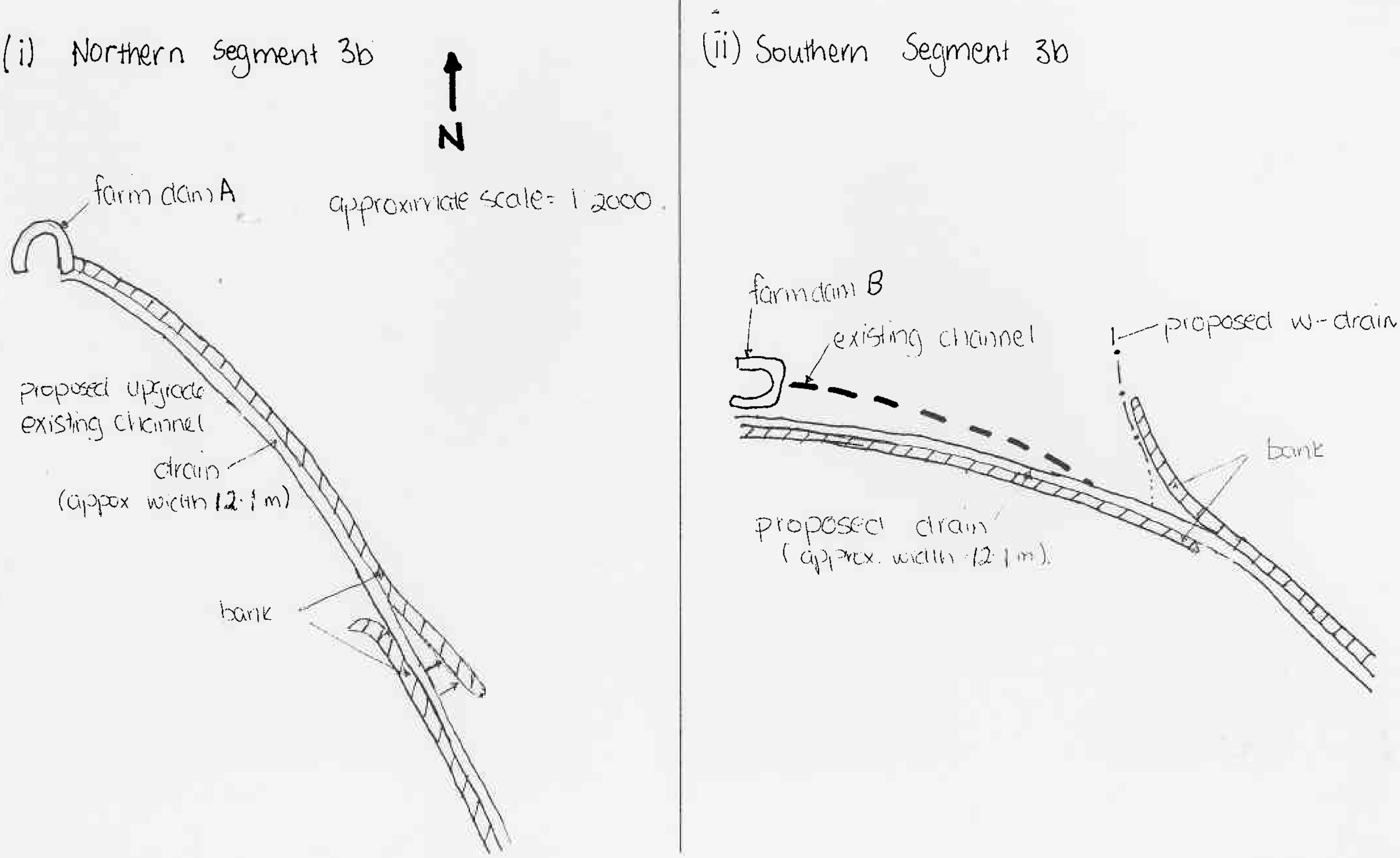


FIGURE 10: DETAIL - DRAIN SEGMENT 2

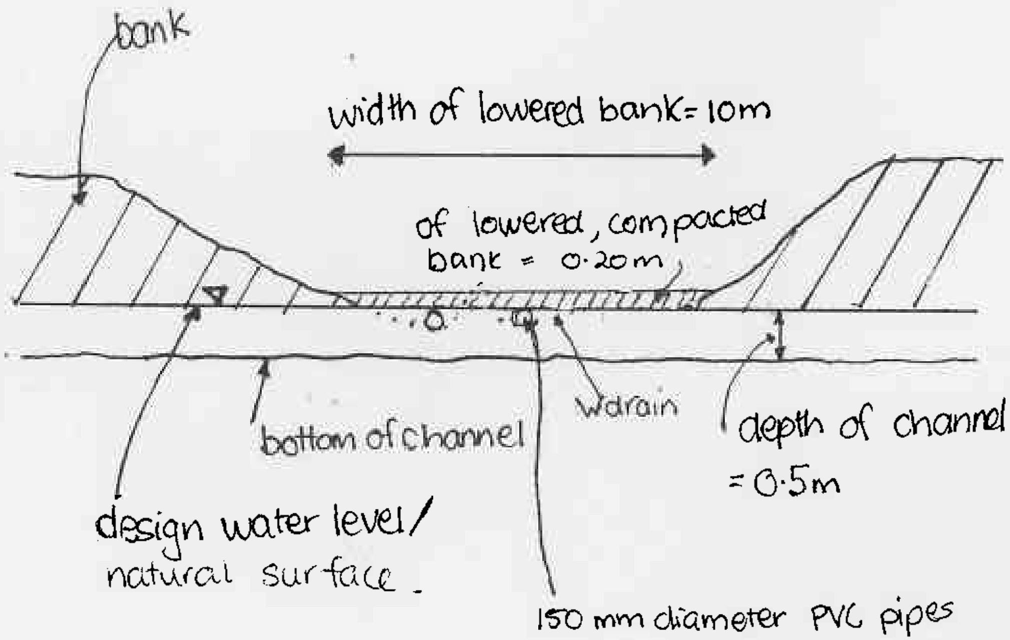
FIGURE 11: DETAIL - DRAIN SEGMENT 3B



Note

1. Required positions and lengths of banks and drains will be indicated to the contractor by pegs in the field.

1. Cross Section at overflow area on Drain Segment 5bN

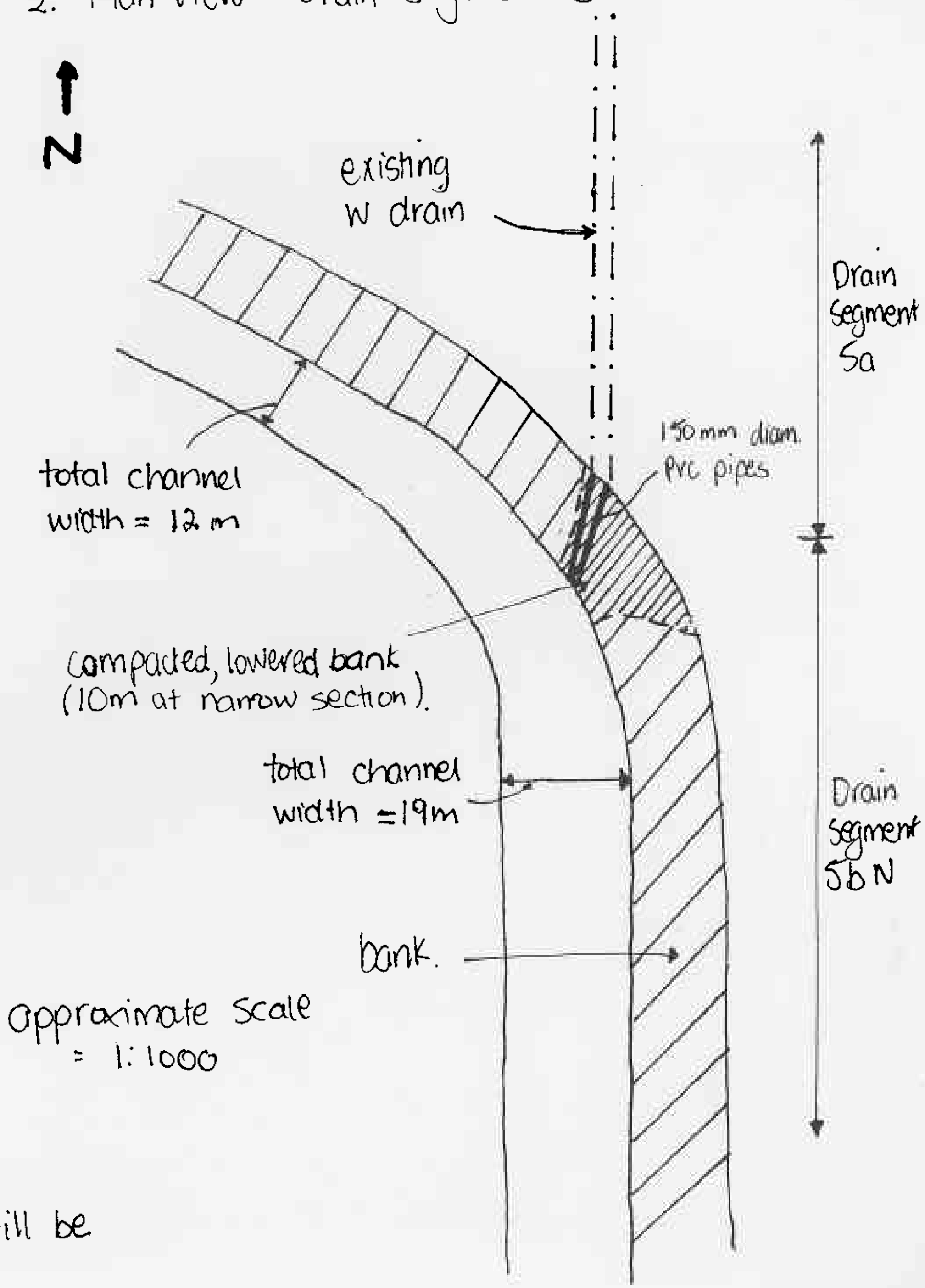


Approximate Scales:

Verticle = 1: 1000

Horizontal = 1: 2000

2. Plan View - Drain Segment 5bN.



approximate Scale = 1: 1000

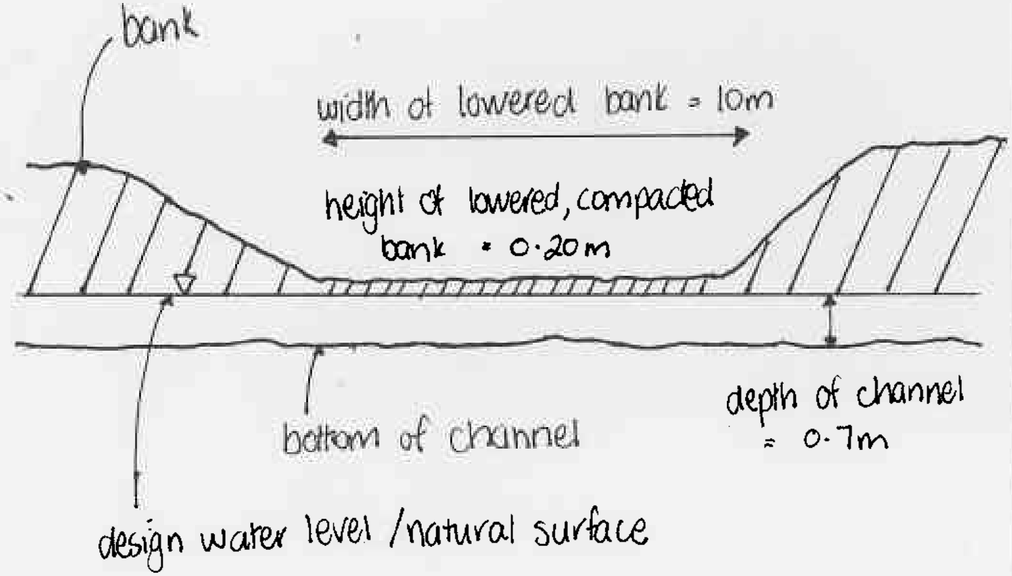
Note

Required positions and lengths of banks and drains will be indicated to the contractor by pegs in the field

FIGURE 12a: DETAIL - OVERFLOW AREA DRAIN 5bN

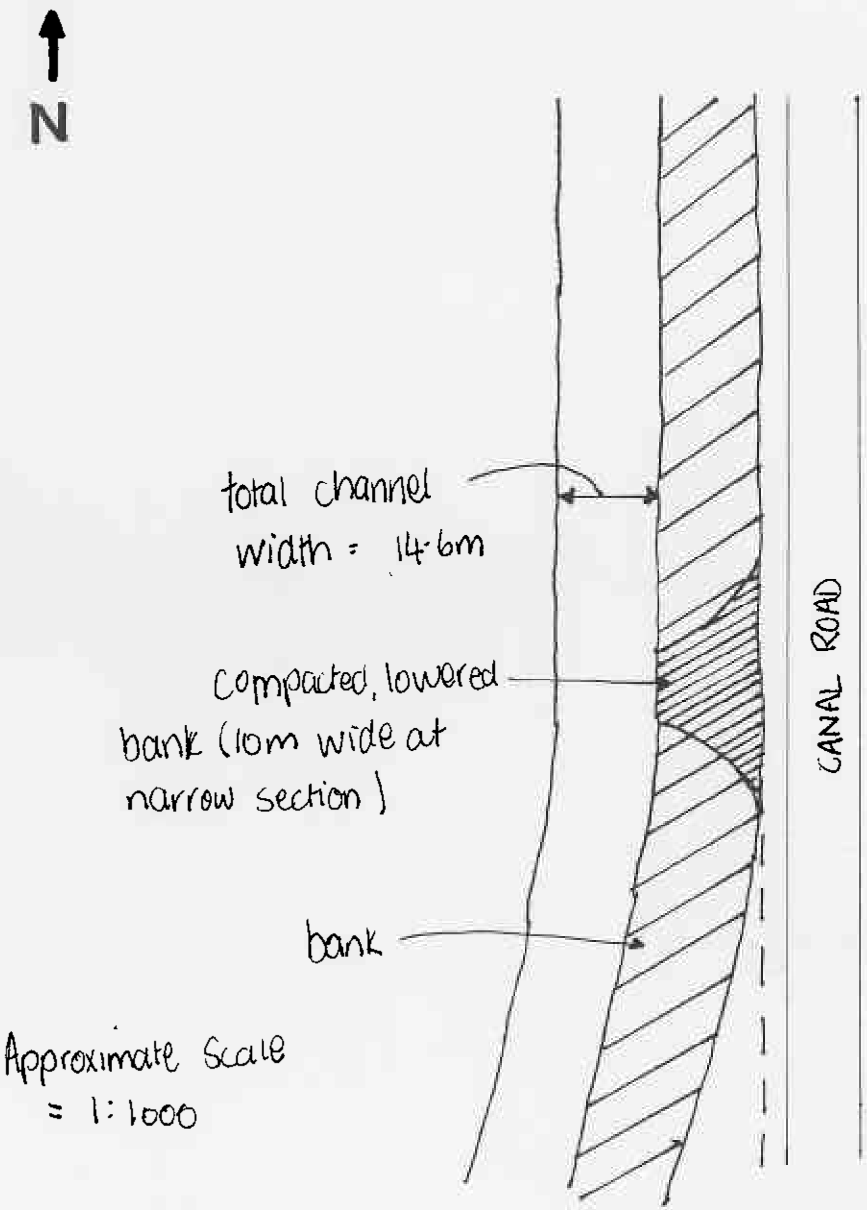
FIGURE 12b: DETAIL - OVERFLOW AREA DRAIN 8aN

1. Cross section at overflow area on Drain Segment 8aW



Approximate Scales:
Verticle = 1:1000
Horizontal = 1:2000

2. Plan View - Drain Segment 8aN



Approximate Scale = 1:1000

Note
Required positions and lengths of banks and drains will be indicated to the contractor by pegs in the field.

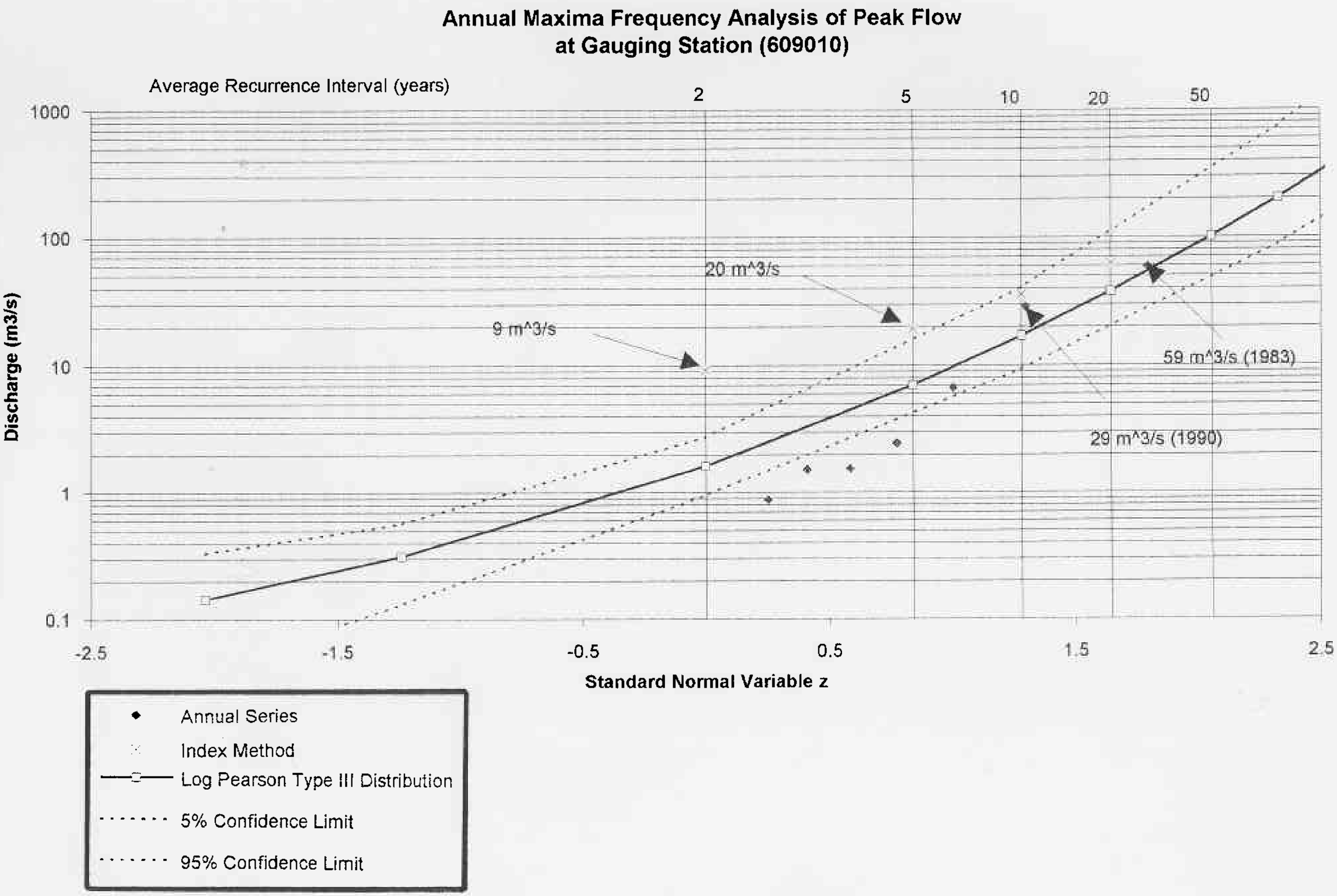


FIGURE 13: ANNUAL MAXIMA FREQUENCY OF PEAK FLOW

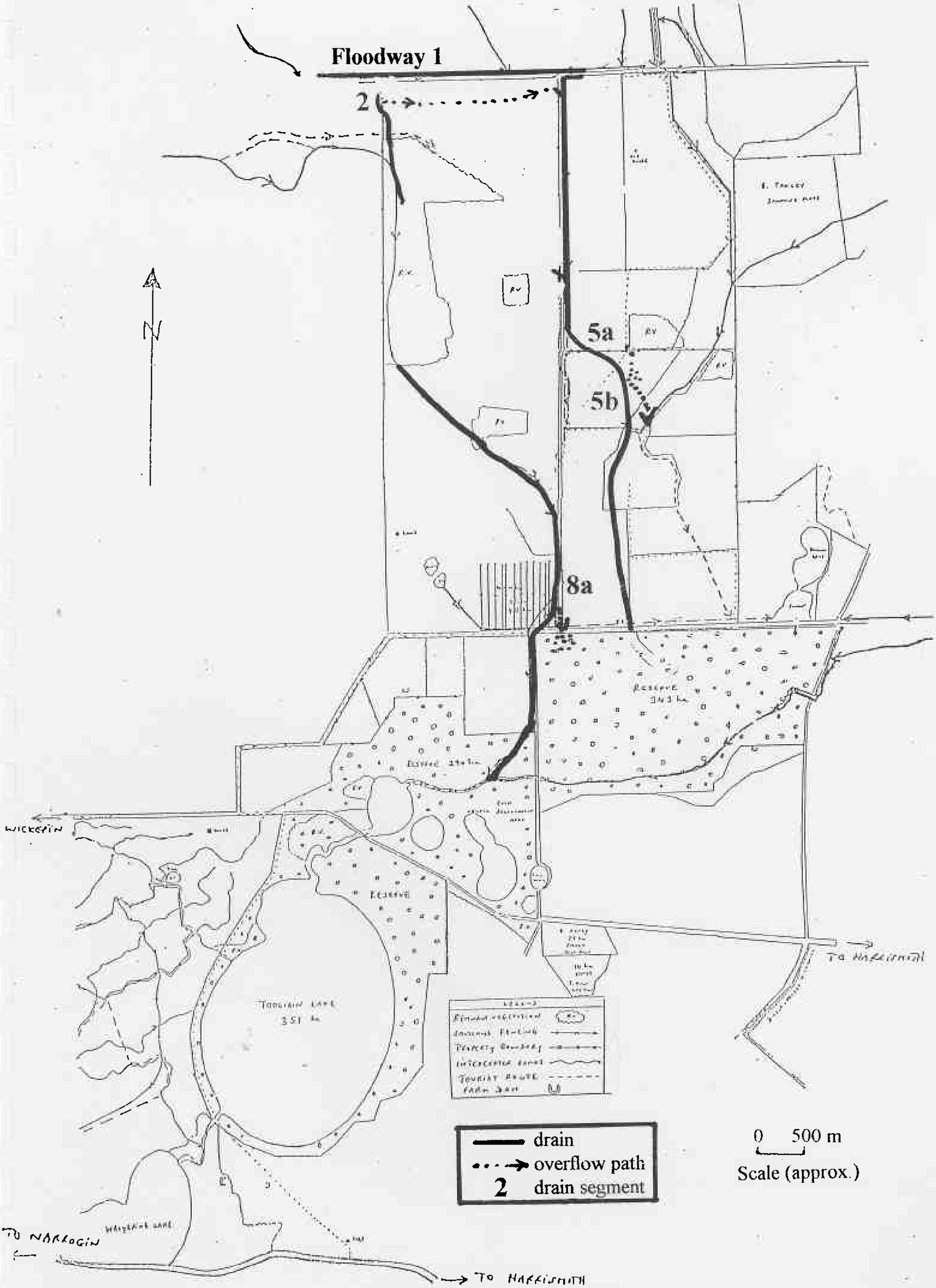


FIGURE 14: OVERFLOW PATHWAYS