EMU CREEK

FLOOD STUDY

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FOREWORD

The State Government's Flood Policy is directed at providing solutions to existing flooding problems in developed areas and to ensuring that new development is compatible with the flood hazard and does not create additional flooding problems in other areas.

Under the Policy, the management of flood liable land remains the responsibility of local government. The State subsidises flood mitigation works to alleviate existing problems and provides specialist technical advice to assist councils in the discharge of their floodplain management responsibilities.

The Policy provides for technical and financial support by the Government through the following four sequential stages:

1.	Flood Study	Determines the nature and extent of flooding.
2.	Floodplain Risk Management Study	Evaluates management options for the floodplain in respect of both existing and proposed development.
3.	Floodplain Risk Management Plan	Involves formal adoption by Council of a plan of management for the floodplain.
4.	Implementation of the Plan	Construction of flood mitigation works to protect existing development. Use of Local Environmental Plans to ensure new development is compatible with the flood hazard.

The Emu Creek Flood Study constitutes the first stage of the process for this area and has been prepared for Weddin Shire Council to define flood behaviour under current conditions.

TABLE OF CONTENTS

Page No.

APPENDICES

LIST OF FIGURES

NOTE ON FLOOD FREQUENCY

The frequency of floods is generally referred to in terms of their Annual Exceedence Probability (AEP) or Average Recurrence Interval (ARI). For example, for a flood magnitude having 5% AEP, there is a 5% probability that there will be floods of equal or greater magnitude each year. As another example, for a flood having 20 year ARI there will be floods of equal or greater magnitude once in 20 years on average. The approximate correspondence between these two systems is:

ANNUAL EXCEEDENCE PROBABILITY (AEP) %	AVERAGE RECURRENCE INTERVAL (ARI) YEARS
0.5	200
1	100
5	20
20	5

Reference is also made in the report to the probable maximum flood (PMF). This flood occurs as a result of the probable maximum precipitation (PMP). The PMP is the result of the optimum combination of the available moisture in the atmosphere and the efficiency of the storm mechanism as regards rainfall production. The PMP is used to estimate PMF discharges using a model which simulates the conversion of rainfall to runoff. The PMF is defined as the limiting value of floods that could reasonably be expected to occur.

ABBREVIATIONS

AEP	Annual Exceedence Probability (%)
AHD	Australian Height Datum
ARI	Average Recurrence Interval (years)
ARR	Australian Rainfall and Runoff, 1998 Edition
BOM	Bureau of Meteorology
DNR	Department of Natural Resources

1. INTRODUCTION

1.1 Study Background

A comprehensive floodplain risk management plan (FRMP) is to be prepared for Emu Creek and its tributary streams as part of a Government program to mitigate the impacts of major floods and reduce the hazards in the floodplain at Grenfell. An important first step in the process of preparing an FRMP is the undertaking of a flood study for the study area. The flood study is the formal starting process of defining management measures for flood liable land and represents a detailed technical investigation of flood behaviour.

Mathematical models of the catchment and the floodplain were developed using detailed field surveys and interpreted to present a comprehensive picture of flooding under present day conditions.

The study objective was to define flood behaviour in the streams in terms of flows, levels and flooding behaviour for flood frequencies ranging between 20 and 200 years average recurrence interval (ARI), as well as for the PMF event.

Flood behaviour was defined using a computer based hydrologic model of the catchment to generate flood flows and a hydraulic model of the stream channels and floodplains to convert flows into flood levels and velocities.

The hydrologic model was a runoff-routing model. As there were no stream flow data available on the Emu Creek catchment, model parameters were estimated using relationships derived in similar investigations and published in the engineering literature. Rainfalls recorded during the historic storm of April 1990 were also applied to the hydrologic model to test the sensitivity of flows to model parameters. Design model parameters were selected after consideration of the results of these studies.

Design storms were then applied to the model to generate discharge hydrographs within the study area. Peak flows from those hydrographs constituted the upstream boundary and tributary inflow inputs to the hydraulic model.

A network hydraulic model was adopted for the hydraulic analysis to model flows in the main channels and floodplains. A one-dimensional model was chosen which allowed for the interaction of flows between the channels and the floodplains, flow through culverts and flow over control structures such as road embankments.

Unfortunately, no flood levels experienced in the April 1990 flood were identified during the survey of the creek undertaken to provide topographic information for the hydraulic model. Several photographs taken at the time of the flood and newspaper reports on the intensity of rainfall and the pattern of flooding experienced in town were supplied by Council. Although these photographs were not taken at the time of the peak, they provided an indication of flow directions, hydraulic controls and extents of inundation.

Flows derived by applying the estimated April 1990 rainfall to the hydrologic model were then applied to the hydraulic model. Modelled flood levels and extents of inundation were compared with the photographic record, to the extent practicable, prior to the selection of model parameters for design flood levels.

The hydraulic model was then used to derive water surface profiles for the design flows generated from the hydrologic model, as well as provide an assessment of the flow distribution and average velocities of flow for the design events.

1.2 Study Tasks

The flood study had three main components:

(1) **Review of available hydrologic and hydraulic data and previous investigations.** A brief was prepared for cross sectional survey of Emu Creek and its tributaries. Gallagher Odell and Garey Consulting Surveyors undertook the survey.

Orthophotomaps of the town area and a contour plan of the study catchments were obtained from the Central Mapping Authority in Bathurst. This information was used to define the sub-catchments for the catchment model and assisted with the identification of flood extents.

Rainfall data recorded at a number of local gauges in April 1990 were supplied by the Bureau of Meteorology. Information on the intensity of rainfall experienced during the storm was also provided in newspaper reports.

(2) **A hydrologic component,** which included preparation and testing of the hydrologic model of the main stream and its tributaries, estimation of design storms and their application to the model.

(3) **A hydraulic component,** which comprised the preparation and testing of the hydraulic model and the definition of the water surface profiles, flows and velocities for the design floods.

1.3 Overview of Report

Section 2 contains background information including a description of the catchments a brief review of the data base available for the study and a discussion on the history of flooding in the study area.

Section 3 deals with the hydrology of the catchments. The RORB runoff-routing program was adopted for this study.

Section 4 describes the computation of design flows using the RORB hydrologic model. This step involved the determination of design storm rainfall depths over the catchments for a range of storm durations, and conversion of the rainfall hyetographs to discharge hydrographs.

Section 5 deals with the development and testing of the hydraulic model. The HEC-RAS software was used for this purpose.

Section 6 details the results of the hydraulic modelling of the design floods using HEC-RAS. Results are presented as tabulations of peak levels, water surface profiles and plans showing indicative extents of inundation for each of the design flood events.

Section 7 contains a list of references.

Supplementary details of the study results are given in the Appendices.

Appendix A presents sketches of the culverts conveying flows from the various drainage lines beneath the street system of the town. These sketches were prepared by Gallagher Odell and Garey.

Appendix B shows the flood hazard and hydraulic categorisation of the floodplain for the 100 year ARI flood.

Appendix C contains tabulations of flood level, discharge and velocity data for design storm events between 20 and 200 year ARI, as well as the Probable Maximum Flood.

2. BACKGROUND

2.1 Catchment Description

Grenfell is drained by several streams which have their headwaters in the foothills to the north of the town and flow in a generally south to south-westerly direction through the urban areas, eventually discharging to Burrangong Creek, which in turn discharges to Bland Creek. **Figure 2.1** is a plan showing the main drainage lines through the town.

There are nine drainage lines running through the town of Grenfell, which together drain a total catchment area of 19.9 km^2 at Holy Camp Road on the southern side of town. These drainage lines have been given the following names in the investigation:

- *The Company Dam Tributary (Upstream of Company Dam)*
- *The Company Dam Overflow (Downstream of the dam)*
- *Star Gully*
- *Star Gully Tributary*
- *Gooloogong Tributary*
- *Emu Creek*
- *Emu Creek Tributary*
- *O'Brien Tributary*
- *Southern Tributary*

The locations and extents of these streams are briefly reviewed below. **Figure 6.9** shows the layout of the creek system. Sketches showing details of the numerous road crossings within the study area are shown in **Appendix A**.

Company Dam Tributary and Overflow

Company Dam Tributary is located on the western side of town about 1 km north of Grenfell and has a catchment area of about 3.1 km^2 at the dam. The dam was constructed in 1867 and is an earthfill dam of 200 m embankment length and retains a volume of 95 ML at full supply level.

The NSW Dams Safety Committee has rated the incremental flood hazard category as "HIGH" because a dambreak would affect residential areas of Grenfell. The normal spillway capacity that is required for a dam with this hazard category is the PMF. The Company Dam has been classified as significantly deficient in spillway capacity, which is currently only 0.15 PMF (DPWS, 1998).

The Dams and Civil Section of the Department of Public Works and Services (DPWS) prepared concept designs of several options for upgrading the dam to achieve a spillway capacity of 0.3 PMF.

The recommended scheme, Option 2, involved enlarging the spillway by 10 metres to 25 m crest length, raising the embankment by 0.85 m and providing a fuse plug at the eastern end of the embankment. The crest of the spillway would be RL 30.3 m and the embankment crest would be RL 32.15 m. According to the DPWS study, Option 2 could convey up to 0.5 PMF prior to the occurrence of the slow erosion of the fuse plug and consequent failure.

As the upgrading will be carried out in the near future, Weddin Shire Council advised that the flood study should assume that the "present day" conditions in the Emu Creek floodplain adopted for this study should represent an upgraded Company Dam, with Option 2 in place.

Downstream of the dam, the Company Dam Overflow runs in a southerly direction for a distance of about 1.25 km crossing North Street (Sketch 127), Melyra Street (Sketch 126) and the Mid Western Highway - also known as Grafton Street (Sketch 123), before joining the right (northern) bank of Emu Creek just upstream of Camp Street. Sketch 121 shows the two streams, which join immediately upstream of the three cell oval culvert beneath Camp Street.

The total catchment area of Company Dam Overflow at the junction, including the area draining to the dam, amounts to 4.1 km^2.

Star Gully and Star Gully Tributary

These catchments are located on the eastern side of town. Star Gully rises in the foothills to the north-east of Star Street and crosses Star Street and Sullivan Street in a three cell box culvert (Sketch 140), before entering the channel running westwards along the northern side of North Street. Flows from the local sub-catchment to the east of Warraderry Street (modelled by Sub-Area P of the RORB catchment model – **Figure 3.1**) join Star Gully via a two cell box culvert (Sketch 134). The combined flows are then conveyed westwards through a triple cell pipe culvert (Sketch 141) opposite Warraderry Street and a twin box culvert further downstream at Parkes Street (Sketch 138).

On the eastern side of Gooloogong Road, flows from the sub catchment to the north of town are conveyed by a tributary denoted the Star Gully Tributary and join the Star Gully channel. This tributary flows westwards across Parkes Street (Sketch 139) before turning southwards and flowing over a weir to join the main arm of Star Gully (Sketch 137). The combined flow then runs under the Gooloogong Road in a two cell oval shaped culvert and joins the Gooloogong Tributary. (Sketch 132)

The total catchment area of Star Gully at the junction with the Gooloogong Tributary amounts to 3.85 km^2.

Gooloogong Tributary

This tributary drains the area to the north of town centred on the Gooloogong Road. The main drainage line runs southwards on the western side of the road to a small dam located in the golf course and continues across rural lands and crosses the stock route in a three cell box culvert (Sketch 133) to join Star Gully at the intersection of North Street and Forbes Street (Sketch 132).

The catchment area of the Gooloogong Road Tributary at the junction with Star Gully amounts to 2.8 km^2.

Emu Creek and Emu Creek Tributary

For the purposes of this study, Emu Creek is assumed to commence at North Street immediately downstream of the junction of Star Gully and Gooloogong Road Tributary.

Emu Creek runs in a south-westerly direction across town, crossing Forbes Street in a two cell oval culvert (Sketch 131). This crossing is relatively inefficient due to the hydraulic losses associated with the diversion of the flow in a westwards direction immediately upstream of the culvert entrance. Further downstream, Emu Creek crosses Melyra Street (Sketch 129) and Dalton Street (Sketch 130).

Flows heading westwards along the southern side of Melyra Street in a box culvert join Emu Creek immediately downstream of the twin cell oval culverts running beneath that road. The general arrangement is shown on Sketch 129. The flows conveyed by the culvert are derived from the O'Brien Tributary, which is described in the following section. Due to the angle at which the two flow streams join, there would be considerable turbulence in the flow near the junction, which would result in a reduction in the hydraulic capacity of the main culverts.

Further downstream, flows from Emu Creek are conveyed beneath Alexandra Street and the Mid Western Highway (Sketches 125 and 122), before joining the Company Dam Overflow on the upstream side of Camp Street (Sketch 121).

The total catchment area upstream of this junction is 13.1 km^2.

Emu Creek continues in a three cell oval culvert beneath Brundah Street (Sketch 120) and as a causeway across Bradley Street (Sketch 117). Emu Creek Tributary which drains the rural lands on the western side of town joins the main stream about 500 m downstream of Bradley Street. This tributary crosses the Mid Western Highway and Manganese Road (Sketches 119 and 118) and has a catchment area of 2.3 km^2 at the junction.

Emu Creek continues southwards for a further 0.8 km, running on the western side of the Sewage Treatment Plant to cross Holy Camp Road in a three cell box culvert (Sketch 115). The total catchment area of Emu Creek and its tributaries at this point is 15.9 km^2 (excluding the Southern Tributary described below).

O'Brien Tributary

This catchment rises in the rural areas on the eastern side of Warraderry Street, where the catchment area amounts to 1 km^2.

West of Warraderry Street, flows are conveyed in an underground drainage system which runs in a north-westerly direction across the intersection of East and Camp Streets and continues across Short and Nash Streets, running along the southern side of Melyra Street to outfall to Emu Creek as a single cell box culvert (Sketch 129). The O'Brien Street Tributary has a catchment area of about 1.6 km^2 at this location.

According to a plan supplied by Council, the underground drainage system comprises a covered channel generally of 1.8 m by 1.2 m dimensions and laid at grades ranging between 1 in 55 and 1 in 115. The plan indicates that the covered channel continues along the southern side of Melyra Street to join the channel of Emu Creek on the southern side of that street. The covered drain between Cross Street and the outfall at Emu Creek is shown as consisting of twin cells each of 1.8 m by 1.2 m dimensions. However, as mentioned, the survey (Sketch 129) identified only a single cell box culvert of 2.1 m by 1.05 m dimensions.

Table 2.1 shows the potential hydraulic capacity of the culvert system assuming that it flows full, with the friction slope equal to the bed slope, and comprises a single cell over its extent.

By comparison of the flows shown in **Table 2.1** with the design flows determined from the RORB catchment modelling described later in **Section 4**, the potential hydrologic capacity of the covered drainage system would be generally in the range 20 to 50 years ARI, assuming that there was sufficient pit inlet capacity within the street system for water to enter and allow the drains to flow at capacity.

The plan upon which the above calculations were based is not a “works as executed” document and is untitled. From observations during the course of the creek survey, there is uncertainty regarding the actual size of the underground drain and whether in fact it extends over the full length shown on the plan. It is also clear from site inspection that there is insufficient pit inlet capacity for the drains of the sizes shown on the plan to flow at their potential capacity.

TABLE 2.1
POTENTIAL HYDRAULIC CAPACITY OF CULVERT
FROM WARRADERRY STREET,
ALONG MELYRA STREET, TO EMU CREEK

Reach	Assumed Dimensions (m)	Hydraulic Capacity (m^3/s)
Warraderry Street to		
	1.8 x 1.2	8.5
East Street to		
	2.4 x 1.2	11.2
Short Street		
	2.75 x 1.2	10.0
Nash Street to		
	2.75 x 1.2	10.0
Melyra Street		
Cross – Forbes	1.8 x 1.2	6.25
Forbes – Emu Creek	2.1 x 1.2	7.4
Outfall at Emu Creek	2.1 x 1.05	4.5

Note: the above estimates of potential capacity are based on uniform flow calculations and assume no restriction is imposed by limitations in the capacity of the pit inlet system. The actual hydraulic capacity is likely to be considerably less than the above values.

For the purposes of the flood study, it was assumed that the underground drain did not have a significant capacity and the flow was conveyed from Warraderry Street to the outfall to Emu Creek as overland flow. The consequences of this assumption are that the computed design water levels over this reach may on the high side. However, the degree of conservatism cannot presently be assessed due to the uncertainties in the available data on the stormwater system.

It is understood from discussions with residents during the survey that the stormwater drainage system was surcharged and considerable overland flow occurred in the Melyra Street area during the April 1990 flood. On that basis, the April 1990 flood was a major flood event. This is supported by catchment modelling described later in **Section 2.3** which indicates that the peak flows experienced in Grenfell may have been in excess of 100 year ARI design flows.

The Southern Tributary

The Southern Tributary rises in the foothills on the eastern side of the Koorawatha-Grenfell railway. Flows from a portion of the catchment are deflected northwards by the railway embankment and eventually are discharged to the western side of the railway by a 5 x 750 mm diameter piped culvert (Sketch 108). These discharges flow across Lawson Park and under Henry Lawson Way in a twin cell box culvert (Sketch 102). Two other culverts (Sketches 100 and 101) convey flows from the remainder of the catchment beneath Henry Lawson Way.

The Southern Tributary flows westwards across rural lands, crossing West Street South, Berrys Road and Bimbi Road (Sketches 110 and 111), and across an unsealed road near the Sewage Treatment Plant (Sketch 113), before turning southwards and crossing Holy Camp Road in a two cell culvert to the east of the Emu Creek culvert (Sketch 114).

The total catchment area of the Southern Tributary at Holy Camp Road is 4 km^2.

2.2 Data Base

There are no stream flow data available on Emu Creek to assist with testing the models. A major storm occurred on 21 April 1990, which was reported by Council to have resulted in inundation of the Emu Creek floodplain, with flows extending into the residential areas bordering the creeks.

Other significant floods are reported to have occurred in the wet year 1931, but there is no quantitative data available for those events.

The Bureau of Meteorology (BOM) supplied rainfall data for the Cowra gauge, which is the closest pluviographic site to Grenfell, and also data from several daily read rain gauges in the area. A report on the April 1990 flood published in the Grenfell Record also provided some useful information on the depth and timing of the most intense burst of rainfall, experienced at Grenfell on the evening of the 21 April 1990. Rainfall data is reviewed in **Section 2.3**.

Following a site inspection of the catchment, a brief was prepared for the cross sectional survey of the channel and floodplain. The survey extended from the Company Dam to downstream of Holy Camp Road.

2.3 April 1990 Storm

2.3.1 Recorded Rainfall Data

Record flooding was experienced in inland NSW during the April 1990 storm. **Table 2.2** shows daily rainfalls recorded at several stations in the vicinity of Grenfell over the four days commencing at 0900 hours on 18 April and continuing to 0900 hours on 22 April.

TABLE 2.2
DAILY RAINFALLS (mm)
APRIL 1990 FLOOD

Rainday	Grenfell Quondong Road 073014	Greenthorpe 073017	Cowra Research Centre 063023
18	0	0	0
19	68	68	41
20	49	37	61
21	35	21	16
22	48	37	28

The Grenfell Recorder of Wednesday 25 April reported that the flood occurred in the early evening of Saturday 21 April and followed several days of heavy rainfall in the area. A total of 202 mm was reported to have occurred in the week prior to the flood.

According to the newspaper report, the downpour responsible for the flood amounted to a fall of 47.5 mm. The resulting flash flood lasted for a total duration of two hours and on this basis, the rainfall burst may have lasted for up to one hour and may therefore have been in excess of a 100 year ARI rainfall event. However, because of the heavy prior rainfall, the catchment would have been wet and infiltration losses very low. Consequently, peak flows may have been considerably higher than 100 year ARI design flows.

Figure 2.2 shows cumulative rainfall depths recorded at the Cowra pluviograph over the four day period 19 – 22 April 1990. Cowra is located about 50 km east of Grenfell and is the nearest site at which the temporal pattern of rainfall is recorded. Inspection of the data confirms that several intense bursts of rainfall were experienced at Cowra in the days prior to 21 April. On the afternoon of 21 April, a burst lasting for about 3 hours was experienced from 3 pm to 6 pm. However, it yielded only 20 mm, much less than the reported rainfall at Grenfell.

Accordingly, it did not appear that the Cowra pluviographic record could be used to provide an accurate assessment of the temporal pattern of rainfall responsible for the flood at Grenfell.

2.3.2 Estimated Flood Flows in April 1990 and Comparison with Observed Flooding Patterns

Estimated Flood Flows

Table 2.3 shows a comparison of peak flows generated by the RORB catchment model for the April 1990 flood with design 100 year ARI peaks at several locations within the drainage system. The April 1990 flows were derived assuming that the 47.5 mm of rainfall reported by the Grenfell Record occurred over 1 hour and had a temporal pattern similar to the design pattern for that duration given in ARR, 1998. Assumed rainfall losses were zero for initial loss and 1 mm/hr for continuing loss. Corresponding design parameters are presented in **Table 3.1**. The 100 year ARI design flows were derived with the design loss values shown on **Table 3.4**.

The results in **Table 2.3** show that the April 1990 flood would have resulted in peak flows slightly greater than 100 year ARI design values if the rainfall occurred in one hour. If the April 1990 storm rainfall occurred in a lesser time, then the resulting peak flows would have been even greater than shown in **Table 2.3.**

TABLE 2.3
COMPARISON OF APRIL 1990
AND 100 YEAR ARI PEAK FLOWS
(values in m^3/s)

Location	100 Year ARI Peak Flows	April 1990 Peak Flows
The Company Dam Tributary and Overflow		
– Inflow to Dam	19	25
– Outflow from Dam	18	22
– Mid-Western Highway	19	18
Star Gully		
– Star Street	16	21
– North Street	22	28
O'Brien Street Tributary		
– Warraderry Street	10	11
– Melyra Street at Junction with Emu Creek	12	16
Emu Creek		
– Mid-Western Highway	47	54
– Camp Street d/s Company Dam Overflow	63	66
– Holy Camp Road	69	71

Observed Flooding Patterns in Grenfell

The Grenfell Record reported that severe flooding was experienced in the streets and bordering allotments due to surcharging of Emu Creek and other waterways. The main areas of flooding appeared to be as follows:

- The north ends of Sullivan and Warraderry Streets were flooded due to surcharging of the stream denoted the Star Gully in the present investigation. This drainage line is of limited capacity and flooding extended into North Street, which became a floodway for flows surcharging the channel.

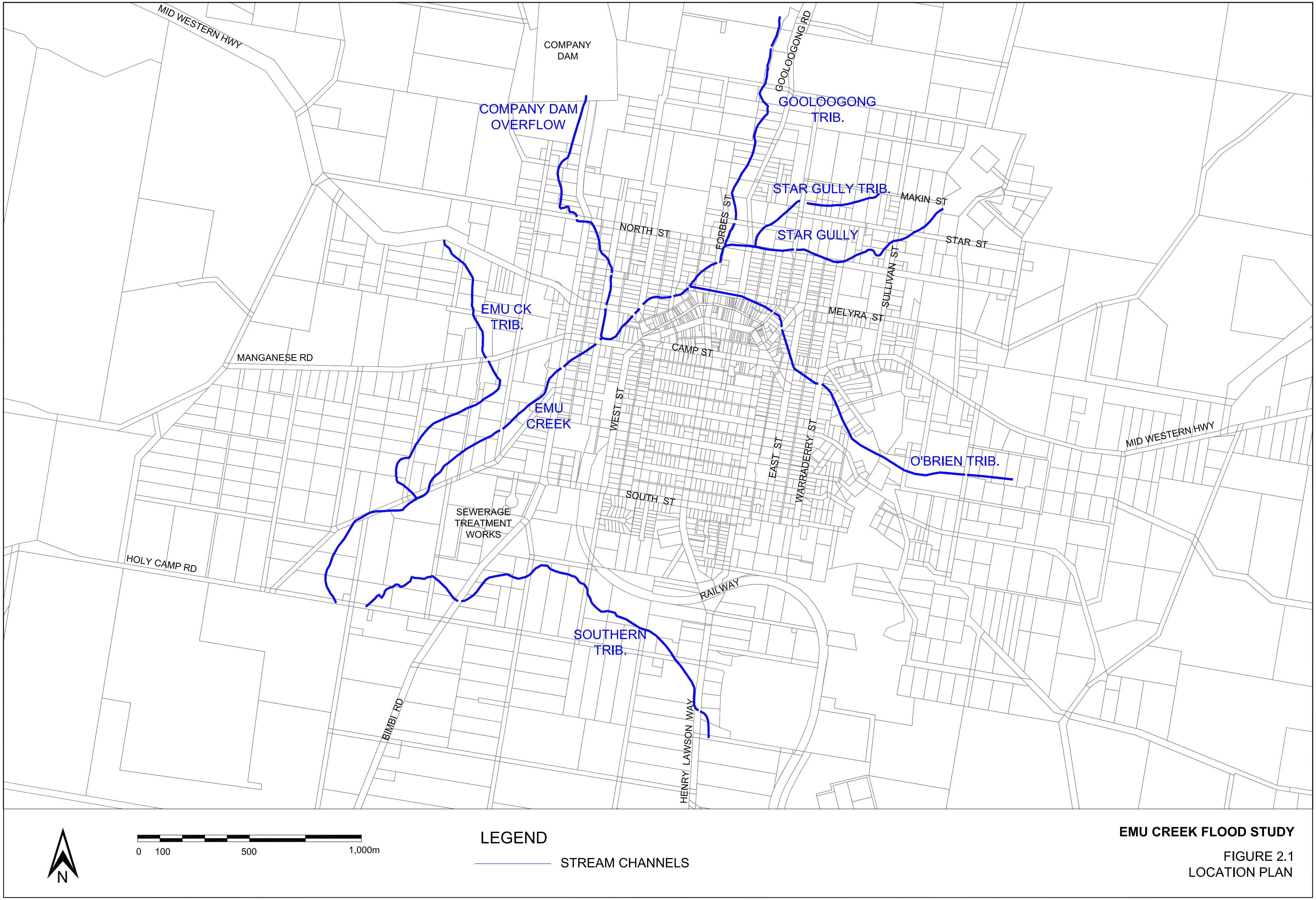
- Floodwaters from the stream denoted the O'Brien Tributary flowed through the allotments on the eastern side of Warraderry Road. Some of the floodwaters overtopped the crown of the road and continued westwards to the intersection of Camp Street and East Street. It is possible that a portion of the flow travelled northwards along Warraderry Street to Melyra Street and then westwards along that street.

- The flow travelling overland along the O'Brien Gully, which could not enter the covered channel due to a lack of inlet capacity, continued across Short Street and into Melyra Street and George Street. The indoor cricket centre and several properties in Melyra Street were also flooded.

- Flooding was also reported due to surcharging of Emu Creek in the Mid-Western Highway Area.

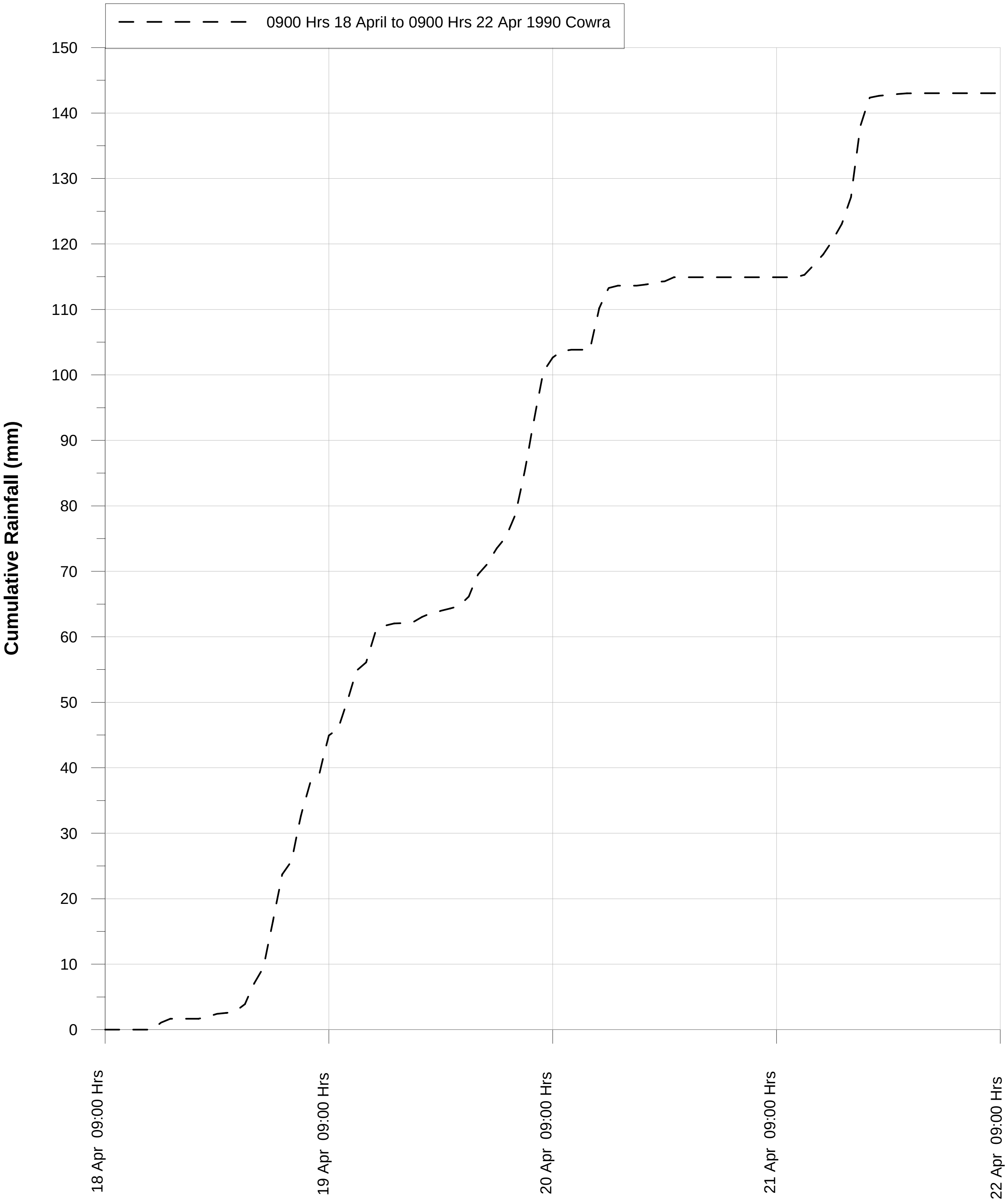
- The stream denoted the Company Dam Overflow in this study also overflowed and several houses in the vicinity of the intersection of Bradley and North Streets were evacuated. The Company Dam would have been filled by runoff from the previous days' rainfalls and would not significantly attenuated peak flows from the catchment.

The peak flows derived by RORB for the April 1990 flood were applied to the hydraulic model of the creek system. Modelled peak water surface profiles are presented in **Section 5** of the report, which also deals with the setting up and testing of the hydraulic model. As discussed therein, the hydraulic model replicates the observed flood behaviour of the April 1990 flood and may be used with confidence to predict flooding patterns for the design events.



EMU CREEK FLOOD STUDY

FIGURE 2.1
LOCATION PLAN



EMU CREEK FLOOD STUDY

Figure 2.2

CUMULATIVE RAINFALL FOR COWRA 0900 hrs 18/4/1990 to 0900 hrs 22/4/1990

3. HYDROLOGY

3.1 Selection of Hydrologic Model

For hydrologic modelling, the practical choice was between the catchment models known as RAFTS, RORB and WBNM, and any of these would have been suitable. Each of these models converts storm rainfall to discharge hydrographs using a procedure known as runoff-routing. There was little to choose technically between these models, however their usage in previous studies in the catchment, as well as the familiarity of the user with the model, were the determining factors in the selection of the RORB modelling approach.

3.2 Brief Review of RORB Modelling Approach

3.2.1 Model Layout

The catchment is divided into sub-areas bounded by drainage divides as shown on **Figure 3.1**. Rainfall on each sub-area is adjusted to allow for infiltration and other losses. The resulting sub-area rainfall-excess is assumed to enter the channel network at a point near the centroid of the sub-area. There, it is added to any existing flow in the channel, and the combined flow is routed through the sub-area storage by a storage routing procedure based on continuity and a storage discharge relationship (equation 3.1).

The overall catchment storage is represented in the model by a network of such storages arranged like the actual channel network. Each model storage represents the actual storage between two nodes of the model. The nodes represent sub-area inflow points, stream confluences, and other points of interest on the catchment or channel network.

3.2.2 Storage Discharge Relations

All storage elements within the catchment are represented via the storage-discharge equation:

$$S = kQ^m \qquad (3.1)$$

where
- S = volume of storage.
- Q = discharge
- k = a storage delay parameter.
- m = a dimensional empirical coefficient

The factor m in equation 3.1 is a measure of the catchment's non-linearity. When m is set equal to unity the catchment's routing response is linear, that is, the ordinates of the discharge hydrograph increase directly in proportion to the ordinates of the hyetograph of rainfall excess. This is the same assumption used in unit hydrograph theory. A value of m less than unity implies that the peak discharge increases at a proportionally greater rate than the rainfall intensity.

In the absence of more catchment specific data, a value of 0.8 is commonly used for flood estimation.

The storage parameter "k" within the general storage equation is modified to reflect the catchment storage and the reach storage as follows:

$$k = kc.kr \qquad (3.2)$$

where kc = an empirical coefficient applicable to the entire catchment and stream network.

kr = a dimensionless ratio called the relative delay time, applicable to an individual reach storage.

3.2.3 Relative Delay Time

The relative delay time of a storage is calculated in the program as follows:

$$k_{ri} = F \frac{L_i}{d_{av}} \qquad (3.3)$$

where k_{ri} = relative delay time of storage i

Li = length of reach represented by storage i, (km)

d_{av} = average flow distance in channel network

F = A factor depending on the type of the reach (=1 for natural channels)

RORB has been used extensively throughout Australia on a wide range of rural and urban catchments. Calibrated values for kc and m for a large number of regions have been developed and have been used to estimate flows on ungauged catchments.

3.3 Estimation of Model Parameters

3.3.1 Coefficients of Storage Equation

The empirical coefficients kc, and m are the principal parameters of the model. In situations where historic rainfall and runoff data are available, the parameters may be derived in a process of model calibration. However, Emu Creek is ungauged and therefore parameters were assessed on the basis of published regional relationships (ARR, 1998) and by comparison with the alternative Probabilistic Rational Method of flood estimation.

For the western region of New South Wales, (ARR, 1998) recommends a relationship which was originally derived for flat to undulating areas in the Northern and Western Regions of South Australia. The relation is:

$$kc = CA^{0.57} \quad (3.4)$$

where A = catchment area in km^2

C = ranges between 1.2 and 1.7 for average stream slopes ranging between 1% and 0.2%.

As Emu Creek has an average slope in excess of 1%, a value of 1.2 should be adopted for C. This results in a value of 6.6 for kc.

For the eastern region of New South Wales, a relationship based on data from 29 catchments east of the dividing range is:

$$kc = 1.22A^{0.46} \quad (3.5)$$

ARR, 1998 states that equation 3.5 should also apply to catchments on the Tablelands and upper Western Slopes of New South Wales. This equation gives a value of 4.8 for kc.

A relationship (equation 3.6) was also derived from 86 catchments in Queensland. Most of the available data was for coastal catchments but values were included for streams west of the Great Dividing Range and near Mt Isa. No regional trends were evident. Equation 3.6 gives a value for kc of 4.3.

$$kc = 0.88A^{0.53} \quad (3.6)$$

All of the above relationships apply for a value of m equal to 0.8.

3.3.2 Rainfall Losses

Walsh et al, 1991 reported on the results of a study into the probabilistic derivation of losses, in particular initial losses, using streamflow data from 22 rural gauged catchments and design rainfalls from Australian Rainfall and Runoff, 1998 (ARR). The design values of initial loss vary with the ARR rainfall zone, flood frequency and the degree of non linearity assumed in the catchment flood hydrograph (RORB) model.

For rainfall Zone 11 west of the divide, recommended initial loss data are as follows:

TABLE 3.1
AVERAGE DESIGN VALUES OF INITIAL LOSS (mm)

ARI (years)	20	50	100	200
Non Linear Model (m = 0.8)	25	20	15	15

These values apply for a continuing loss rate of 2.5 mm/h.

3.4 Testing the RORB Model

This section discusses the sensitivity of flows generated by the RORB model to variations in the RORB model parameters.

Estimates of peak flows for the 100 year ARI generated by varying model parameters are presented in Section 3.4.1.

For comparison purposes, Section 3.4.2 presents peak flows estimated from the Probabilistic Rational Method, which is in common usage for the derivation of flood flows on rural ungauged catchments in NSW.

After consideration of the results of the various approaches, a set of RORB model parameters was selected for the design flood estimation of Chapter 4 of the report. These parameters are presented on **Table 3.4**.

3.4.1 Estimates of 100 Year ARI Flood Flows

Peak flows generated by RORB with the three estimates of kc derived from the formulas in the engineering literature are shown in **Table 3.2**. These flows assume the design rainfall losses shown on **Table 3.4**, namely, 15 mm initial loss and 2.5 mm/h continuing loss.

TABLE 3.2
SENSITIVITY OF PEAK DISCHARGE TO Kc
EMU CREEK DOWNSTREAM OF HOLY CAMP ROAD
100 YEAR ARI

Source	Kc	Discharge m^3/s
Lipp (Equation 3.4)	6.6	58
Kleemola (Equation 3.5)	4.8	78
Qld Data (Equation 3.6)	4.3	87

Note: These flows apply downstream of the junction of Emu Creek and the Southern Tributary

3.4.2 Estimates of Design Peak Flows from Probabilistic Rational Method

For comparison purposes, the Probabilistic Rational Method (PRM) was also used to provide an estimate of peak flows. This method is recommended for use in eastern New South Wales for rural catchments up to 250 km^2 in area (ARR, 1998).

Steps involved in this method are:

i) Determine the critical rainfall duration as the time of concentration in hours from the equation:

$$tc = 0.76A^{0.38} \quad (3.7)$$

where A = Catchment area (km^2)

ii) For this duration and the selected frequencies, determine the design rainfall intensities Iy (mm/h).

iii) Compute the runoff coefficient for an ARI of 10 years and adjust via the frequency factor FFy to determine the Y year runoff coefficient Cy.

iv) Compute the design flood magnitude Qy (m^3/s) from the formula:

$$Qy = 0.278 \times FFy \times Iy \times A \quad (3.8)$$

Using this approach, estimates of Qy were derived for various flood frequencies were prepared. The results are shown on **Table 3.3**.

TABLE 3.3
PEAK DISCHARGES DOWNSTREAM OF HOLY CAMP ROAD
ESTIMATED BY PRM
Values in m^3/s

20 yr ARI	50 yr ARI	100 yr ARI
20	32	46

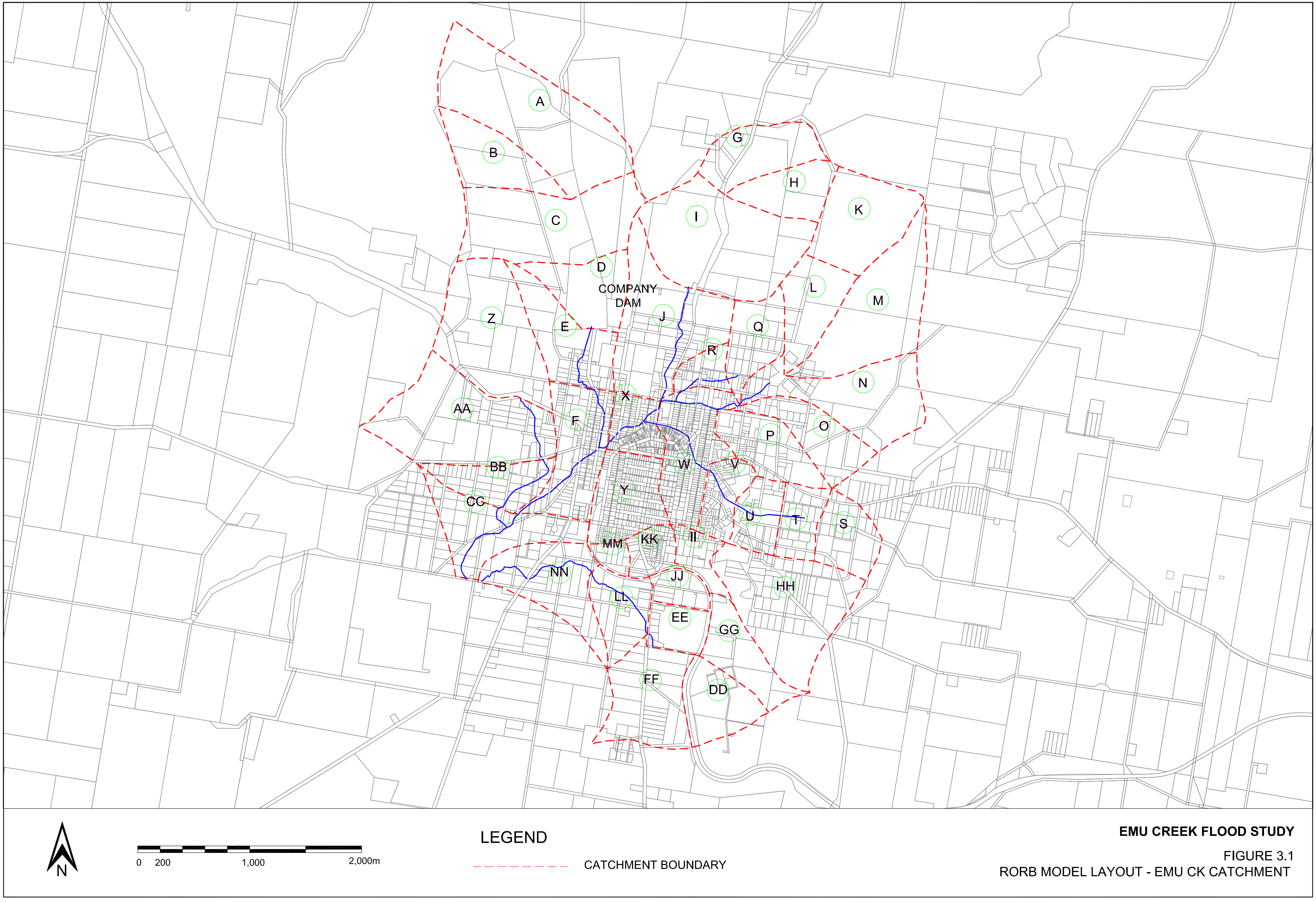
Peak flows estimated by the PRM for the 100 year ARI flood are considerably smaller than flows derived using RORB.

3.4.3 RORB Model Parameters Adopted for Design Flood Estimation

After consideration of the above analyses, the following set of model parameters has been used for design flood estimation. The kc value of 4.8 used for estimation of floods ranging between 20 and 200 year ARI is based on the Kleemola results summarised as equation 3.5. For the PMF, a linear model (m=1) was adopted as studies have shown that catchments tend to behave in a linear manner for extreme floods, which fill the floodplain (see Section 4.3 for further discussion).

TABLE 3.4
DESIGN RORB MODEL PARAMETERS
EMU CREEK

Parameter	Recurrence Interval year ARI				
	20	**50**	**100**	**200**	**PMF**
Initial Loss	25	20	15	15	15
Continuing Loss	2.5	2.5	2.5	2.5	2.5
Kc	4.8	4.8	4.8	4.8	5.5
m	0.8	0.8	0.8	0.8	1.0



EMU CREEK FLOOD STUDY

FIGURE 3.1
RORB MODEL LAYOUT - EMU CK CATCHMENT

4. DESIGN FLOOD ESTIMATION

4.1 Design Storms

4.1.1 Rainfall intensity

The procedures used to obtain temporally and spatially accurate and consistent intensity-frequency-duration (IFD) design rainfall curves for the Emu Creek catchment are presented in Chapter 2 of ARR (1998). Design storms for frequencies of 5, 20, 50 and 100 year ARI were derived for storm durations ranging between 1 hr and 6 hrs. The procedure adopted was to generate IFD data for each catchment by using the relevant charts in Volume 2 of ARR (1998). These charts included design rainfall isopleths, regional skewness and geographical factors.

4.1.2 Areal Reduction Factors

The rainfalls derived using the processes outlined in ARR (1998) are applicable strictly to a point. In the case of a large catchment of over tens of kilometres square it is not realistic to assume that the same rainfall intensity can be maintained over a large area, an areal reduction factor is typically applied to obtain an intensity that is applicable over the entire area.

However, as the area of the Emu Creek catchment is only 19.9 km^2, below the junction with the Southern Tributary, the reduction in rainfall intensities would be quite small and accordingly, no reduction in point rainfalls was made for this study.

4.1.3 Temporal Patterns

Temporal patterns for various zones in Australia are presented in ARR (1998). These patterns are used in the conversion of a design rainfall depth with a specific ARI into a design flood of the same frequency. Patterns of average variability are assumed to provide the desired conversion. The patterns may be used for ARIs up to 500 years where the design rainfall data is extrapolated to this ARI.

The derivation of temporal patterns for design storms is discussed in Chapter 3 of ARR (1998) and separate patterns are presented in Volume 2 for ARI less than 30 years and ARI greater than 30 years. The second pattern is intended for use for rainfalls with ARIs up to 100 years, and to 500 years in those cases where the design rainfall data in Chapter 2 of ARR (1998) are extrapolated to this ARI.

4.2 Design Hydrographs

The RORB model was run with the above parameters to obtain design hydrographs for input to the hydraulic model. Peak flows at the model outlets for the critical storm duration which ranged between 90 minutes and 3 hours depending on location and flood frequency are shown on **Table 4.1.** As expected, the small catchments in the study area are "flash flooding" with water levels rising to their respective peaks within 1 to 3 hours after the inception of heavy rainfall, depending on location within the drainage system.

TABLE 4.1
DESIGN PEAK DISCHARGES
EMU CREEK TRIBUTARY STREAMS

Location	Peak Flow (m^3/s)				
	20 yr ARI	50 yr ARI	100 yr ARI	200 yr ARI	PMF
The Company Dam Tributary and Overflow					
– Inflow to Dam	7.6	13.6	19.1	22.5	86
– Outflow from Dam	6.7	12.5	17.7	21.0	84
– Mid-Western Highway	6.9	12.5	17.3	20.7	70
Star Gully					
– Star Street	6.4	11.5	16.1	19.0	75
– North Street	8.8	15.8	21.9	26.0	99
O'Brien Tributary					
– Camp St/East St Intersection	3.5	6.6	8.3	10.0	41
– Melyra Street at Emu Creek Junction	6.5	10.4	12.0	14.6	59
Emu Creek					
– Mid-Western Highway	19.0	33.7	46.9	55.6	193
– Camp Street d/s Company Dam	25.5	44.6	63.3	75.6	254
– Holy Camp Road (u/s jn. with Southern Tributary.)	28.6	48.4	68.9	82.5	238
– d/s Holy Camp Road (d/s jn. with Southern Tributary.)	33.7	58.3	80.5	95.9	279
Southern Tributary					
– Holy Camp Road (u/s Emu Ck jn.)	7.9	14.1	19.6	23.2	65

Note : Flows apply for the critical storm durations of 90 minutes to 3 hours, as applicable.

4.3 Probable Maximum Flood

Estimates of probable maximum precipitation were made using the Generalised Short Duration Method (GSDM) as described in the Bureau of Meteorology's Bulletin 53 (BOM, 1994). This method is appropriate for estimating extreme rainfall depths for catchments up to 1000 km^2 in area and storm durations up to 6 hours.

The steps involved in assessing PMP for the Emu Creek catchment are briefly as follows:

- Calculate PMP for a given duration and catchment area using depth-duration-area envelope curves derived from the highest recorded US and Australian rainfalls.

- Adjust the PMP estimate according to the percentages of the catchment which are meteorologically rough and smooth, and also according to elevation adjustment and moisture adjustment factors.

- Assess the design spatial distribution of rainfall using the distribution for convective storms based on US and world data, but modified in the light of Australian experience.

- Derive storm hyetographs using the temporal distribution contained in Bulletin 53, which is based on pluviographic traces recorded in major Australian storms.

The design flows derived for events up to the 200 year ARI were based on the assumption that the catchment behaved in a non-linear manner. A value of 0.8 was adopted for the exponent m of the catchment's storage-discharge equation (Equation 3.1).

However, adoption of a non-linear modelling approach for the PMF resulted in peak flows which were over eight times the magnitude of the 100 year ARI peaks. For example, the modelled peak discharge on Emu Creek at Holy Camp Road was 588 m^3/s compared with 68.9 m^3/s for the 100 year ARI flood. The corresponding values for the Southern Tributary at the Holy Camp Road crossing were 141 m^3/s, versus 19.6 m^3/s.

From previous investigations, multiples between PMF and 100 year ARI peak flows of between 3 to 6 may be expected for small catchments such as those draining the study area at Grenfell. The reason for the larger multiple modelled in the present case is the assumption that the catchment functions in a non-linear manner at the extreme flood level.

While there is evidence of non-linear response (i.e. a value of m not equal to unity) over the range of observed floods in most natural catchments, it is unclear whether this effect persists to the PMF. At that magnitude of flooding, the routing response depends on the relative efficiency of the drainage system and the amount of storage on the catchment.

The V-shaped valleys of the headwaters of the Emu Creek tributaries have comparatively small overbank areas and therefore a theoretical value of 0.75 - 0.8 for the exponent m of the storage versus discharge relationship used by RORB in the rainfall-runoff routing process for each sub-area of the model. This indicates that the headwaters of the creeks should continue to behave in a non-linear manner for extreme floods.

On the other hand, the storage in the lower floodplains, where most of the flow is conveyed as shallow overland flow, may have the effect of increasing the value of m for extreme flood events. Also, the flow resistance in extreme floods may be increased by debris, erosive processes and increased turbulence, and all of these influences may promote linear behaviour.

A sensitivity analysis of the PMF was undertaken with the RORB models run in both a non-linear and a linear manner. For the linear model case, the coefficient kc in the storage versus discharge relationship was adjusted according to the recommendation contained in the RORB Manual. This resulted in a 15 per cent increase, from the value of kc from 4.8 for the non-linear case, to 5.5 (linear).

Peak flows for the linear case were within the 3 to 6 times expected range. RORB model parameters for the linear model have been adopted for this investigation and are shown on **Table 3.4**.

Design PMP hyetographs were derived for durations ranging between 1 and 6 hours and applied to the model using the linear model parameters. One in 100 year rainfall losses were adopted for the PMF.

The 2 hour storm was found to be critical. Peak flows are shown in **Table 4.1.**

By comparison, the peak PMF discharges at the dam as estimated in the upgrading study (DPW, 1998) were in the range of 190 – 280 m^3/s, depending on the range of RORB model parameters investigated. No comparisons with other flood estimation procedures eg. the PRM, or comparison of derived PMF flows with other frequencies eg. the 1 in 100 year discharge were made in the DPW, 1998 study. The 190 m^3/s estimate, which lies at the lower end of the range, compares with an estimate of 84 m^3/s in the present study and is 10 times the estimate for the 100 year ARI discharge. The 280 m^3/s for the upper end of the DPW, 1998 range is around 15 times the 1 in 100 year estimate.

The PMF flows derived in the DPW, 1998 study are considered to be on the high side. An overestimate may be satisfactory for the intended purpose, that is for the design of a dam spillway, where a conservative estimate of flows is acceptable. However, as use of those flows may incorrectly categorise land as flood liable, such overestimates should not be used for the present investigation.

5. HYDRAULICS

5.1 Selection of Hydraulic Model

A model was required which could route flows through main streams and their tributaries, and produce information on the distribution of flow, velocities and water surface elevations at nominated locations. The model was to be capable of analysing hydraulic conditions at the culvert and bridge crossings of the streams, and capable of adjustment so that it could analyse the effects of possible modifications such as levees, channel enlargement, adjustments to bridge waterways or future land use changes on the floodplain, all of which could influence flooding behaviour.

Few commercially available hydrodynamic models contain all the features required for this present study. One however, HEC-RAS, has the required capabilities and is readily available to all potential model users at minimal cost.

HEC-RAS is a one-dimensional hydraulic modelling package developed by the Hydrologic Engineering Centre of the US Army Corps of Engineers and has seen widespread application in Australia in recent years.

5.2 Emu Creek Model Layout

5.2.1 Model Structure

The model consisted of cross sections derived from ground survey. The choice of section locations depended on the need to accurately represent features on the floodplain which influence hydraulic behaviour (e.g. bridge constrictions, changes in channel and floodplain dimensions, weir controls) as well as supplying adequate flood information in existing urban areas.

5.2.2 Model Boundary Conditions

Upstream Boundary

Peak flows derived from RORB provided the boundary conditions at the upstream end of the model. The flow was adjusted along the modelled reach to account for runoff from the various sub-catchments.

Downstream Boundary

The hydraulic model was extended 300 m downstream of Holy Camp Road, the nominal downstream limit of the study area. The assumption of uniform flow conditions (i.e. friction slope equals bed slope) was used to derive starting water surface levels at the downstream boundary of the model. The derived flood levels at Holy Camp Road were not sensitive to uncertainties in starting water surface levels.

5.3 Testing Hydraulic Model of Emu Creek

5.3.1 General

The main physical parameter for HEC-RAS is hydraulic roughness. There are other parameters such as contraction and expansion head loss coefficients which are of a hydraulic nature but which have the potential to affect computed flood levels in the vicinity of the road crossings in Grenfell.

There are no historic flood level data available to assist with calibration of the model. Accordingly, roughness was estimated from site inspection, past experience and values contained in the engineering literature (Arcement and Schneider, 1984; Cowan, 1956; Barnes, 1967).

5.3.2 Roughness Values for Stream Channel

Although several factors affect the selection of an "n" value for the channel, the most important factors are the type and size of the materials that compose the bed and banks of the channel as well as its shape. Cowan, 1956 developed a procedure for estimating the effects of these factors.

In this procedure, the value of n may be computed by the following equation:

$$n = (nb + n1 + n2 + n3 + n4)\, m \quad \ldots\ldots\ldots \; 5.1$$

where	nb	=	a base value of n for a straight, uniform, smooth channel in natural materials
	n1	=	a value added to correct for the effects of surface irregularities
	n2	=	a value for variations in shape and size of the channel cross section
	n3	=	a value for obstructions to flow
	n4	=	a value for vegetation and flow conditions
	and m	=	a correction factor for meandering of the channel

5.3.3 Roughness Values for Floodplain

It is usually necessary to determine roughness values for channels and floodplains separately. The fabric of a floodplain can be quite different from that of a channel. The physical shape of a floodplain is different and the vegetation covering a floodplain is typically different from that found in a channel.

Cowan's procedure was altered by Arcement and Schneider, 1984 to assess n values for a floodplain, using equation 5.1, where:

nb	=	a base value of n for the floodplain's natural bare soil surface, with no vegetation cover
n1	=	a value to correct for the effects of surface irregularities on the floodplain

n2	=	a value for variations in shape and size of the floodplain cross section
n3	=	a value for obstructions on the floodplain
n4	=	a value for vegetation on the floodplain
m	=	a correction factor for the sinuosity of the floodplain

Arcement and Schneider, 1984 also present photographs of densely vegetated floodplains for which roughness coefficients have been verified from historic flood data. These photographs were used together with application of equation 5.1 for estimating floodplain roughness.

TABLE 5.1
"BEST ESTIMATE" OF HYDRAULIC ROUGHNESS VALUES
Emu Creek and Tributary Streams

Location	Channel	Floodplain
Company Dam Overflow	0.05-0.06	0.08
Star Gully	0.05-0.06	0.05-0.08
Gooloogong Road Tributary	0.05-0.06	0.08
O'Brien Street Tributary	0.035-0.06	0.06-0.08
Emu Creek	0.05-0.065	0.08
Southern tributary	0.05-0.065	0.08

5.3.4 Modelling the April 1990 Flood

Peak water surface profiles as modelled for the April 1990 and 100 year ARI design floods are shown on **Figure 5.1** for Emu Creek between the junction with the Goolagong Tributary and Camp Street and on **Figure 5.2** for Star Gully between Makins Street and Cross Street just downstream of the intersection with Star Gully Tributary.

The two water surface profiles are shown for comparison purposes. There are no flood level data available for the April 1990 flood to verify the model, only the anecdotal evidence that this was a major flood event with the flooding pattern as described in the Grenfell Record's report of 25 April 1990 (**Section 2.3.2**). As discussed below, the results derived from the hydraulic modelling are in agreement with the reported pattern of flooding.

Over the modelled reach of Emu Creek, the April 1990 flood levels are around 200 mm higher than the 100 year ARI flood and would have a larger flood extent than that event, which is shown on **Figure 6.9**.

On Emu Creek, all of the road crossings would have been overtopped and would have influenced flood levels to the next upstream crossing. The results indicate that the road crossings would impose a considerable restriction on flow during major flood events. For example, at the Mid Western Highway crossing of Emu Creek, shown on **Figure 5.1**, the modelled difference in flood levels across the culvert crossing was in excess of 0.5 m. Similar results were experienced in the upstream crossings.

On Star Gully, shown on **Figure 5.2**, all of the crossings would have been overtopped in April 1990 and flooding would have extended into the allotments on the southern side of North Street, which runs parallel with the channel.

At the weir on the prolongation of Bogalong Street, at River Station 230, the channel invert of Star Gully falls by about 0.8 m and flows are restricted to a width of around 6.4 m within the weir section itself. Consequently the weir acts as a hydraulic control structure and causes considerable "heading up" of water levels upstream, with a return to sub-critical flow conditions occurring via a hydraulic jump on the downstream side of the weir, as flows approach the backwater imposed by the Cross Street culvert.

Modelled peak water surface levels on the O'Brien Tributary for the April 1990 flood were similar to those modelled for the 100 year ARI design event. By analogy with the 100 year ARI flood extents shown on **Figure 6.9**, the model predicted that in April 1990, flooding would have extended into the commercial areas bordering Melyra and George Streets as the flow travelled westwards towards Emu Creek.

In summary, the hydraulic model replicates the observed flood behaviour of the April 1990 flood and may be used with confidence to predict flooding patterns for the design events.

6. HYDRAULIC MODELLING OF DESIGN FLOODS

6.1 Introduction

This Chapter deals with the derivation of flood behaviour along Emu Creek and its tributaries using the HEC-RAS hydraulic model. The flows generated by RORB and presented in **Table 4.1** have been used, in conjunction with the best estimate values of hydraulic roughness shown in **Table 5.1** for the modelling of design flood levels.

6.2 Results of Hydraulic Modelling

6.2.1 Presentation of Results

Design water surface profiles are shown in **Figures 6.1 to 6.8**. The indicative extent of flooding for the 20 and 100 year ARI design floods and the PMF have been plotted on GIS base maps and are shown in **Figure 6.9**.

The locations of the cross sections used in the hydraulic modelling of the streams are shown on both the water surface profiles and the extents of inundation diagram. **Figure 6.9** also shows peak water surface levels at selected locations. Further information on peak levels at intermediate modelled locations is presented in **Appendix C**.

At the road crossings, there are two types of cross sections, in keeping with the methodology used by HEC-RAS to model bridges. The shorter cross sections are located in the immediate vicinity of the bridge and are used to define the jet of flow entering and leaving the waterway opening, which is confined within the channel. The longer cross sections model the roadway above the bridge, which functions as a broad crested weir in the event of major flood events overtopping the road. These sections extend a sufficient length to encompass the extent of road which is effective for weir flow.

In the floodplain areas remote from the bridges, the sections were surveyed a sufficient length to encompass the extent of the waterway which is *effective for the conveyance of flow*. At some locations, the cross sections did not encompass all of the inundated area. At such locations, the orthophotomaps were used to assist with the estimation of the extent of inundation.

However, the orthophotomaps have a relatively coarse contour interval of 2 m. Consequently, the extents of inundation are approximate only and should not be used to identify the degree of flood affectation, or otherwise, of individual allotments located within the floodplain. The extent and depth of inundation within individual allotments would need to be confirmed by a site specific survey, and interpolation of the peak flood levels estimated at the various cross sections of the hydraulic model.

Peak water surface elevations and the average flow and velocity distributions across the waterway section are tabulated in **Appendix C**. These tables show the results at locations along the streams which are denoted “River Stations”. The River Stations are identifiers of each cross section included in the model and are also shown at the foot of the water surface profile diagrams, where they are cross referenced to the surveyed sections.

Uncertainties associated with numerical hydraulic modelling are such that water levels are usually rounded off to the nearest 100 mm. However, in the present study water surface profiles along the steeper reaches of the creek do not show large differences in elevation, indicating that large increases in flow result in relatively small increases in water level. Consequently, the results have generally been presented to two decimal places (i.e. to the nearest 10 mm), to highlight differences in the model results for the various floods.

Similarly, flow velocities have been presented to two decimal places to show differences between the various flood events. The velocities are average values within the modelled waterway. There will probably be a gradation of velocities across the floodplain, with velocities reducing as the depth of flow reduces as it approaches the flood fringe.

6.2.2 Discussion of Results

The streams in the study area are shallow and rather ill defined, apart from Emu Creek which is the main drainage line running through town. The channel of Emu Creek is several metres deep in places and up to 5 m wide.

Emu Creek was modelled for a distance of 2.85 km from Forbes Street to Holy Camp Road. To remove errors due to uncertainties in the assumed water surface elevation at the downstream end of the study area (Holy Camp Road), a cross section of the floodplain about 300 m south of Holy Camp Road was synthesised using the orthophotomap and adopted as the downstream boundary of the model.

Gooloogong Creek is also reasonably well defined with a depth of channel around 1.5 m and top width up to 4 m.

Star Gully, as it flows along the Northern side of North Street, appears to be an improved channel. However, it has limited capacity. In major flood events it would be surcharged with 100 year ARI flows extending across the road. Consequently, North Street would act as a floodway for major events.

The gradients of the streams are quite steep and in the range 0.9 to 1.4 per cent. Star Gully and the Gooloogong Tributary are the steepest streams with slopes around 1.1 to 1.4 per cent and Emu Creek is the flattest, averaging 0.6 per cent gradient over the 2.85 km modelled reach.

Flows up to the 20 year ARI magnitude would be conveyed within the channels of the various streams and their immediate overbanks, except in the case of the Southern Tributary where the channel is of such low capacity that the extent of inundation could reach several hundred metres at the 20 year ARI level.

Flow velocities in the channel would in general be no greater than 1-1.5 m/s for the full range of events. Flow on the overbanks is characteristic of shallow, relatively slow moving overland flow, with depths no greater than several hundred millimetres for events up to the 100 year ARI and velocities generally around 0.2 to 0.5 m/s.

Peak water levels do not vary greatly for the various design storm events, with a difference in levels between the 20 year ARI level and the 200 year ARI level generally ranging between 200 and 400 mm. The PMF flood levels are generally around 1 m higher than the

100 year ARI levels, but there is considerably less of an increase in some of the steeper reaches of the creek system, as discussed below.

There are several locations in the drainage system where it is likely that some of the flow which surcharges the channels in major floods at bridge crossings would be captured by the roadway and flow laterally along the road, or would escape from the channel and flow as shallow overland flow with the prevailing grade.

Star Gully and Star Gully Tributary, for example, tend to run parallel with the natural surface contours over part of their modelled reaches and have relatively indistinct channels of low hydraulic capacity. When these channels overflow, there is the potential for surcharging flows to move away from the line of the creek with the prevailing grade, as shallow overland flow. Accordingly in those areas, the pattern of flow may have some two-dimensional characteristics.

Where escapes from the channel are likely to occur, they have been labelled on **Figure 6.9** by an arrow which also shows the direction of flow and the likely frequency at which they commence. For example, some of the flow on Star Gully Tributary in the area between Makins Street and C.S. 57 would be expected to escape southwards at the 100 year ARI. Because of this, there would be little increase in flood level in the creek for events greater than the 100 year ARI. This is evident in the water surface profile for that stream shown on **Figure 6.2**.

Detailed modelling of these escapes, as well as several other overland flow paths also shown on **Figure 6.9** by an arrow, would require the implementation of a true two-dimensional (in plan) hydraulic model which would operate on a horizontal grid of around 10 metre centres. An airborne laser survey would also be required to provide the detailed survey information required. Such a modelling approach would not be justified in the present case. Interpretation of the results of the one-dimensional hydraulic modelling approach adopted in the investigation has provided an adequate representation of flooding at Grenfell.

6.3 Sensitivity Study - Variation in Hydraulic Roughness

As mentioned previously, hydraulic roughness along the creeks was estimated from site inspection, past experience and values shown in Arcement and Schneider, 1984. The hydraulic model allows for the sensitivity of variations in roughness across the waterway section to be assessed, by multiplying the base roughness by specified relative roughness factors. The factors apply to the channel and floodplains.

Prior to adopting peak water levels for the design floods, model runs were undertaken to test the sensitivity of results to variations in hydraulic roughness.

Due to the steepness of the streams, peak flood levels are relatively insensitive to variations in roughness. For example, for a 20 per cent increase in roughness applied globally to the model, the maximum increase in flood levels on Emu Creek for the 100 year ARI flood within the town amounted to 270 mm. On the steeper streams, the increases in flood levels due to increased roughness were smaller, amounting to 200 mm for Star Gully, 140 mm for the Gooloogong Tributary and less than 100 mm for O'Brien Tributary.

The sensitivity of results to variations in hydraulic roughness confirmed that the 500 mm of freeboard on design flood levels, which is commonly adopted for planning purposes, would be appropriate for the Emu Creek floodplain.

6.4 Use of Model Data to Assess Flood Levels

Consideration was given to presenting the model results as contours of peak water surface levels for the various floods. However, this approach was not appropriate due to the steep bed gradient and the considerable drops in water levels across the road crossings, which introduce discontinuities in the water surface profiles.
Accordingly, the following approach is suggested for using the flood data when assessing peak flood levels within the study area.

- Mark the location for which flood information is required on **Figure 6.9**. This diagram will give an initial (but not necessarily final) estimate on whether or not that particular location is flood prone.
- Identify from **Figure 6.9** the particular stream on which the site is located and an adjacent identifying point such as a surveyed cross section or a nearby road crossing. Note whether the site is upstream or downstream of any adjacent culvert crossing. This is important because of the considerable water level drop across most of the culverts.
- Consult the appropriate water surface profile (ie **Figures 6.1** to **6.8**), locate the position of the site on the reach and obtain a first estimate of peak flood level for the various frequencies by scaling.
- Consult the tabulations of flood data in **Appendix C** to refine the estimate of flood levels and obtain further information on the local distribution of flows and velocities.

Note that as mentioned previously, the above procedure will only yield the flood level adjacent to the point of interest. A detailed site survey would be required to assess the extent of flood affectation of individual allotments.

6.5 Floodway and Flood Hazard Areas

6.5.1 Floodways

According to the Floodplain Development Manual, 2005, the floodplain may be subdivided into the following:

- Floodways;
- Flood storage; and
- Flood fringe

Floodways are those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with obvious naturally defined channels. Floodways are the areas that, even if only partially blocked, would cause a significant redistribution of flow, or a significant increase in flood level which may in turn adversely affect other areas. They are often, but not necessarily, areas with deeper flow of areas where higher velocities occur.

Flood Storage areas are those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. If the capacity of a flood storage area is substantially reduced by, for example, the construction of levees or by landfill, flood levels in nearby areas may rise and the peak discharge downstream may be increased. Substantial reduction of the capacity of a flood storage area can also cause a significant redistribution of flood flows.

Flood Fringe is the remaining area of land affected by flooding, after floodway and flood storage areas have been defined. Development in flood fringe areas would not have any significant effect on the pattern of flood flows and/or flood levels.

Floodplain Risk Management Guideline No 2 Floodway Definition, offers guidance in relation to two alternative procedures for identifying floodways. They are:

- **Approach A**. Using a *qualitative approach* which is based on the judgement of an experienced hydraulic engineer. In assessing whether or not the area under consideration was a floodway, the qualitative approach would need to consider; whether obstruction would divert water to other existing flow paths; or would have a significant impact on upstream flood levels during major flood events; or would adversely re-direct flows towards existing development.

- **Approach B**. Using the hydraulic model, in this case HEC-RAS, to define the floodway based on *quantitative experiments* where flows are restricted or the conveyance capacity of the flow path reduced, until there was a significant effect on upstream flood levels and/or a diversion of flows to existing or new flow paths.

One quantitative experimental procedure commonly used is to progressively encroach across either floodplain towards the channel until the designated flood level has increased by a significant amount (for example 0.1 m) above the existing (un-encroached) flood levels. This indicates the limits of the hydraulic floodway since any further encroachment will intrude into that part of the floodplain necessary for the free flow of flood waters – that is, into the floodway.

The HEC-RAS software has the capability to determine the stations at each cross section which define the hydraulic floodway. It computes the encroachment stations so that the conveyance within the encroachment cross section (at some higher level) is equal to the conveyance of the natural cross section at the natural water level. This higher water level is specified as a fixed amount above the un-encroached flood profile (e.g. 100 mm).

Both **Approaches** were used in assessing the floodways in the present study. The extents of the 100 year ARI floodway adopted on the various streams are shown on **Figure B1** of **Appendix B.** The results are summarised below:

- *The Company Dam Overflow (Downstream of the dam).* The floodway may be defined by the extent of inundation reached by the 20 year ARI flood as far as North Street. Downstream of that location, the floodway widens and most of the waterway cross section is important for the conveyance of flow.

- *Star Gully*. Between Makins Street and Sullivan Street, the extent of inundation reached by the 20 year ARI flood is a reasonable representation of the 100 year ARI floodway. Further downstream, the floodway widens and includes North Street which conveys significant flows.

- *Star Gully Tributary.* There are significant flows on the overbank. The hydraulic analysis confirmed that the 100 year ARI extent of inundation was a reasonable representation of the floodway.

- *Gooloogong Tributary.* The extent of inundation reached by the 20 year ARI flood is a good representation of the floodway, except at its downstream end at Cross Section 25 near the junction with Emu Creek, where it widens slightly.

- *Emu Creek.* This is the main stream in the drainage network. Hydraulic analyses supported the adoption of the 100 year ARI extent of inundation as the floodway between North Street and Camp Street. In this reach, constrictions of the flow resulted in a cumulative increase in afflux which was compounded by the "natural" constrictions imposed by the existing bridge crossings. The analyses showed that further downstream, the 20 year ARI flood extent could be adopted as the floodway.

- *Emu Creek Tributary*. In general, the floodway approximates the extent of 20 year ARI flood, except in the vicinity of Manganese Road where the extent of inundation widens due to the effects of the bridge and would be a conservative representation of the 100 year ARI floodway.

- *O'Brien Tributary*. In the undeveloped portion of the catchment above Warraderry Street, the 20 year ARI extent defines the 100 year ARI floodway. Downstream of that point the floodway widens to the extent of 100 year ARI inundation. Melyra Street functions as a floodway during major flood events.

- *Southern Tributary.* Hydraulic analysis showed that the 20 year ARI extent could be adopted as the floodway upstream of Cross Section 4. Further downstream, where the inundation extends over several hundred metres, the floodway is somewhat narrower than the 20 year ARI extent.

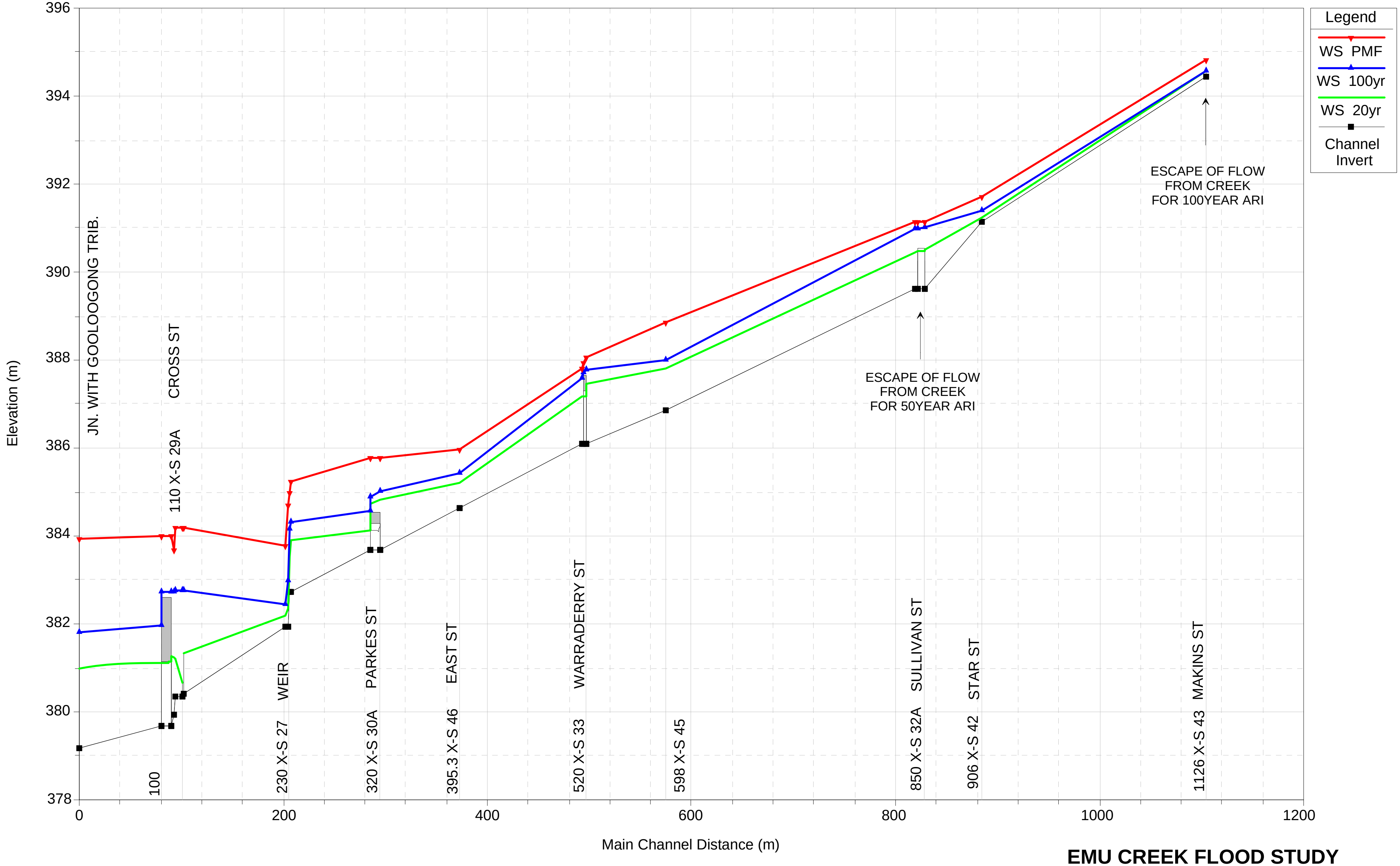
6.5.2 Provisional Flood Hazard

Flood hazard categories may be assigned to flood affected areas in accordance with the procedures outlined in the Floodplain Development Manual, 2005.

Flood prone areas may be provisionally categorised into *Low Hazard* and *High Hazard* areas depending on the depth of inundation and flow velocity. Flood depths as high as 0.8 m in the absence of any significant flow velocity are representative of Low Hazard conditions. Similarly, areas of flow velocities up to 2.0 m/s but with minimal flood depth also represent Low Hazard conditions.

Figure B2 in **Appendix B** shows the flood hazard for the 100 year ARI defined according to the above principles. In most of the Low Hazard areas the velocity of flow would be expected to be quite low, less than 0.2 – 0.4 m/s and the flow would be shallow and of an overland flow nature.

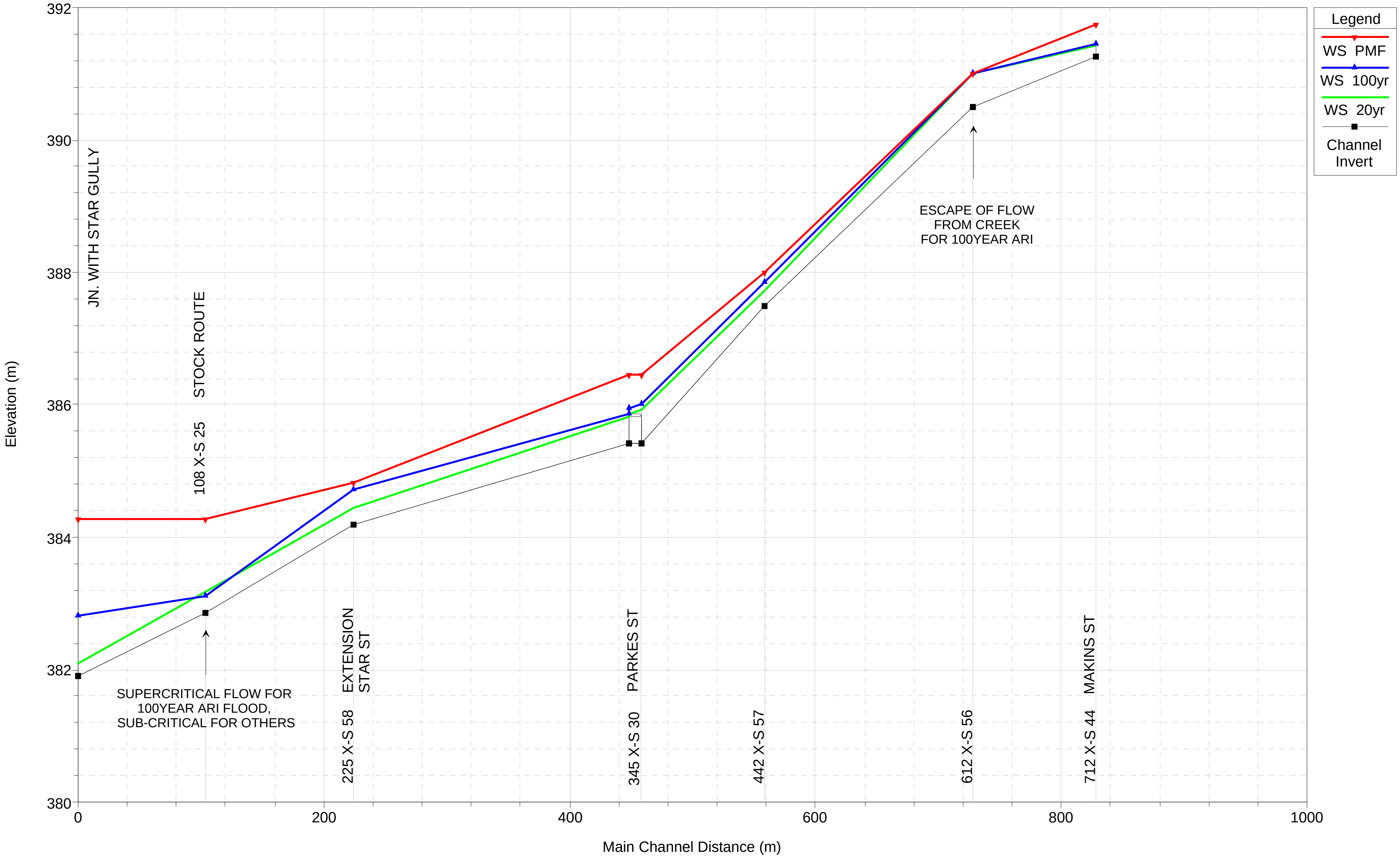
The Flood Hazard assessment presented herein is based on considerations of depth and velocity of flow and is provisional only. As noted in the Floodplain Development Manual, other considerations such as rate of rise of floodwaters and access to high ground for evacuation from the floodplain should also be taken into consideration before a final determination of Flood Hazard can be made. These factors are normally taken into account in the *Floodplain Risk Management Study* for the catchment, which is the next stage in the flood management process for the area.



EMU CREEK FLOOD STUDY

Figure 6.1

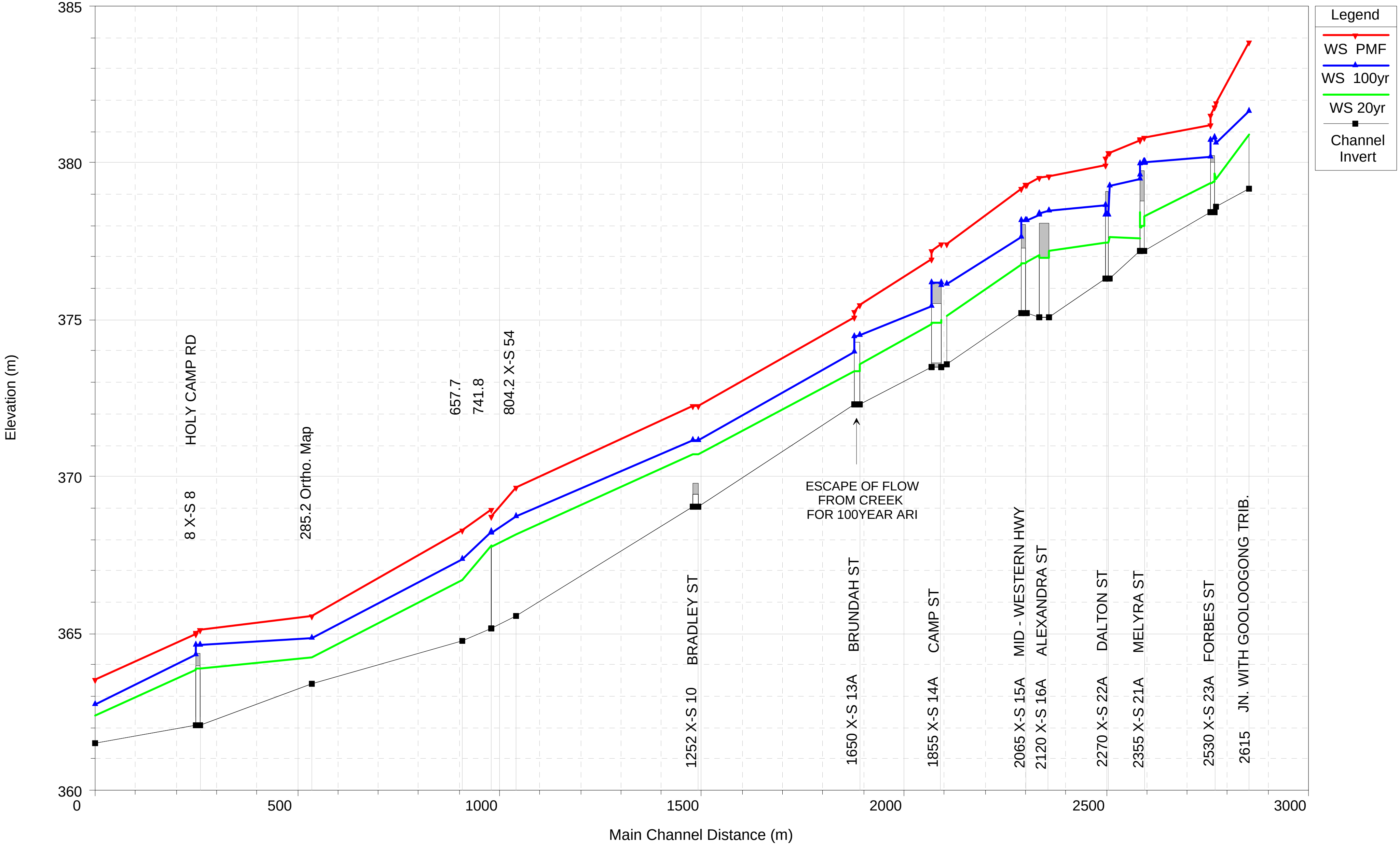
DESIGN WATER SURFACE PROFILES
STAR GULLY



EMU CREEK FLOOD STUDY

Figure 6.2

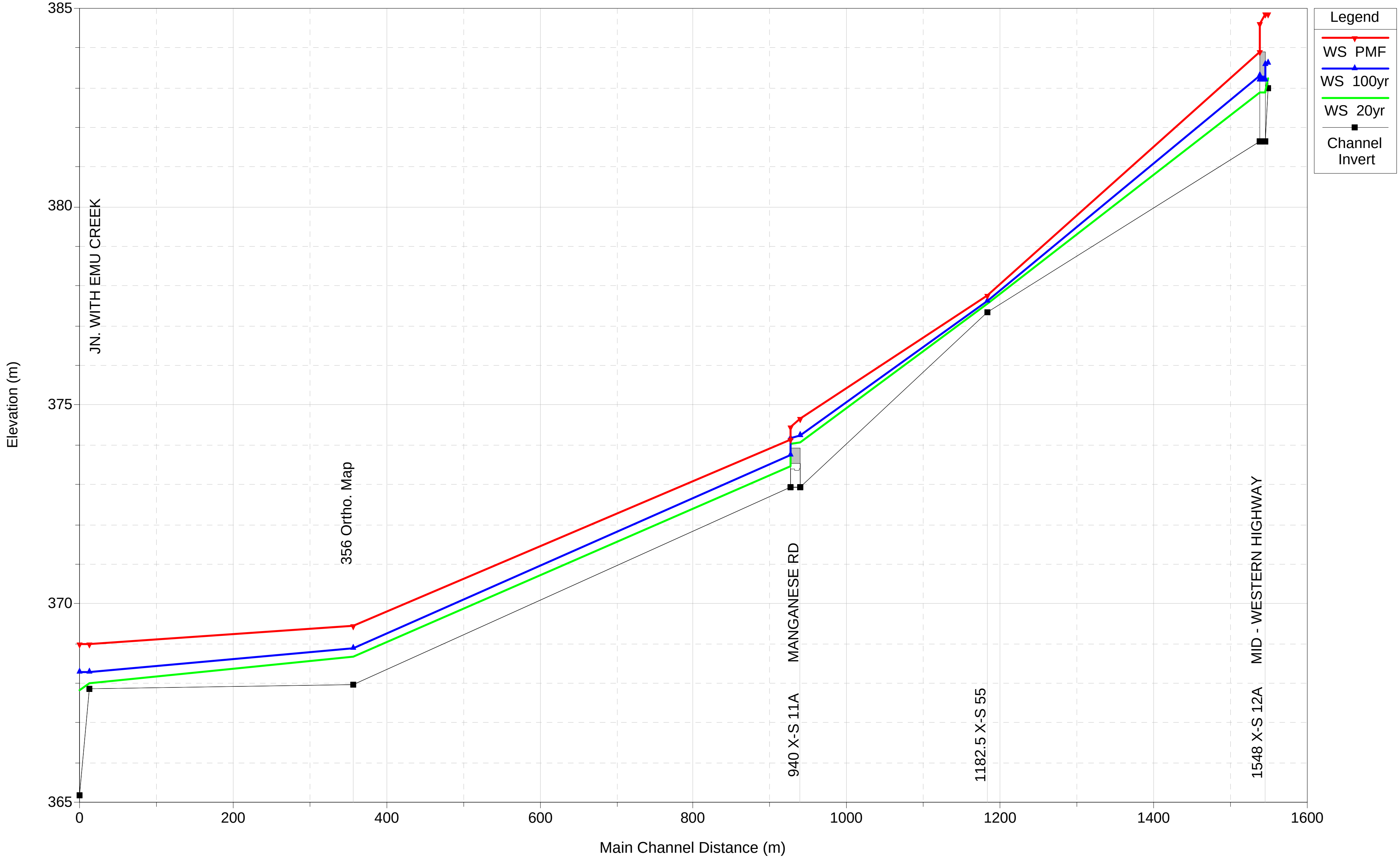
DESIGN WATER SURFACE PROFILES
STAR GULLY TRIBUTARY



EMU CREEK FLOOD STUDY

Figure 6.3

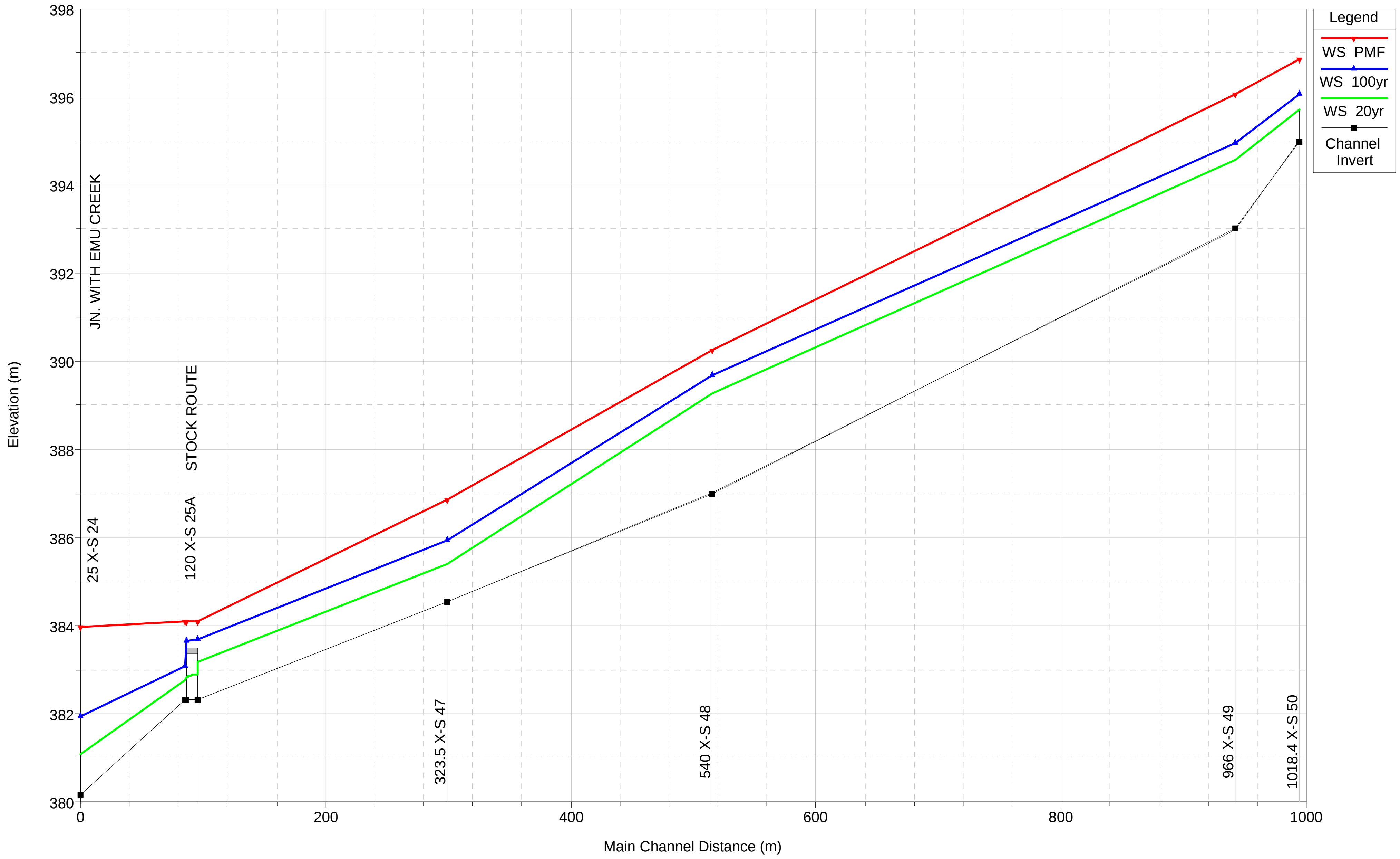
DESIGN WATER SURFACE PROFILES
EMU CREEK



EMU CREEK FLOOD STUDY

Figure 6.4

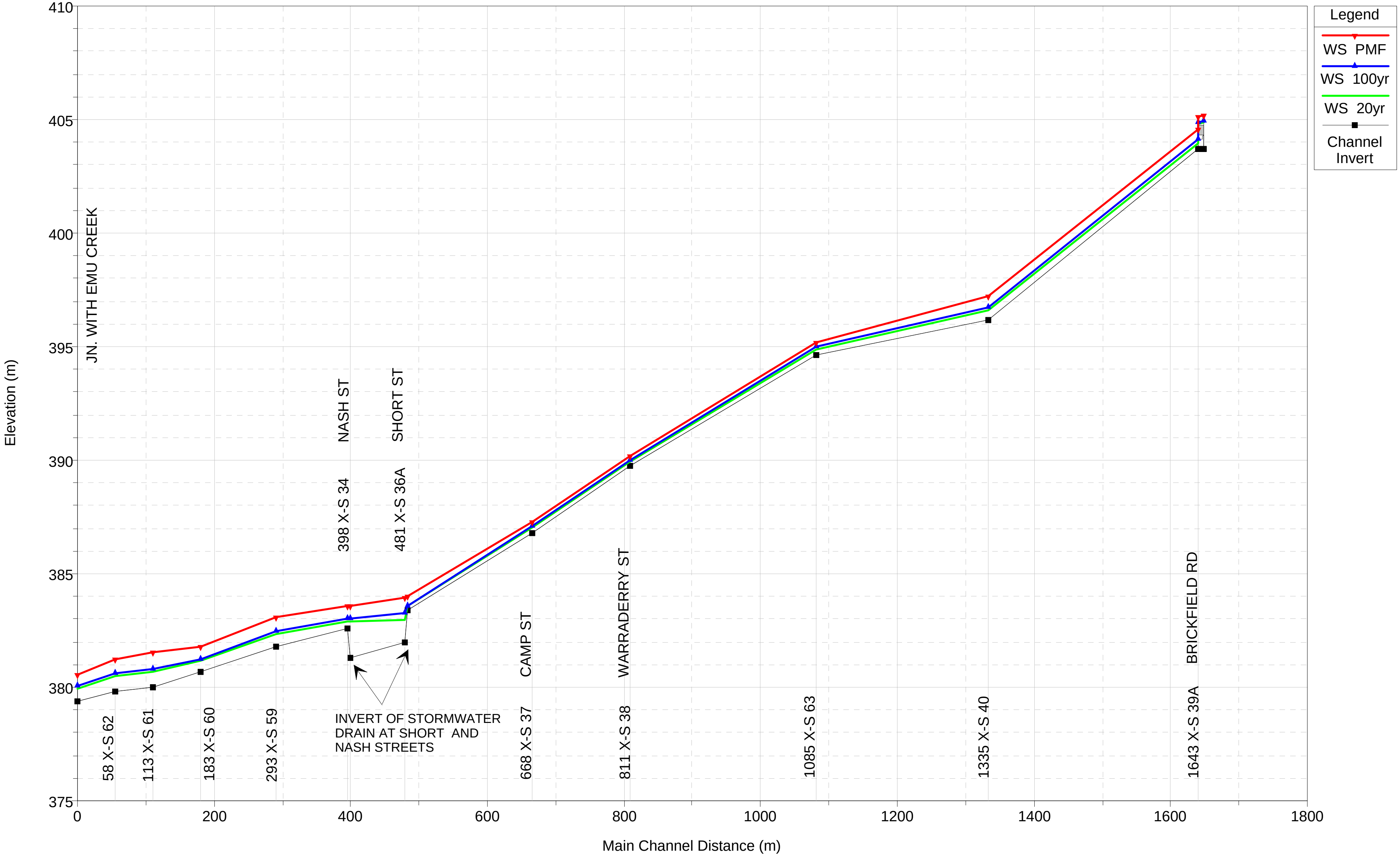
DESIGN WATER SURFACE PROFILES
EMU CREEK TRIBUTARY



EMU CREEK FLOOD STUDY

Figure 6.5

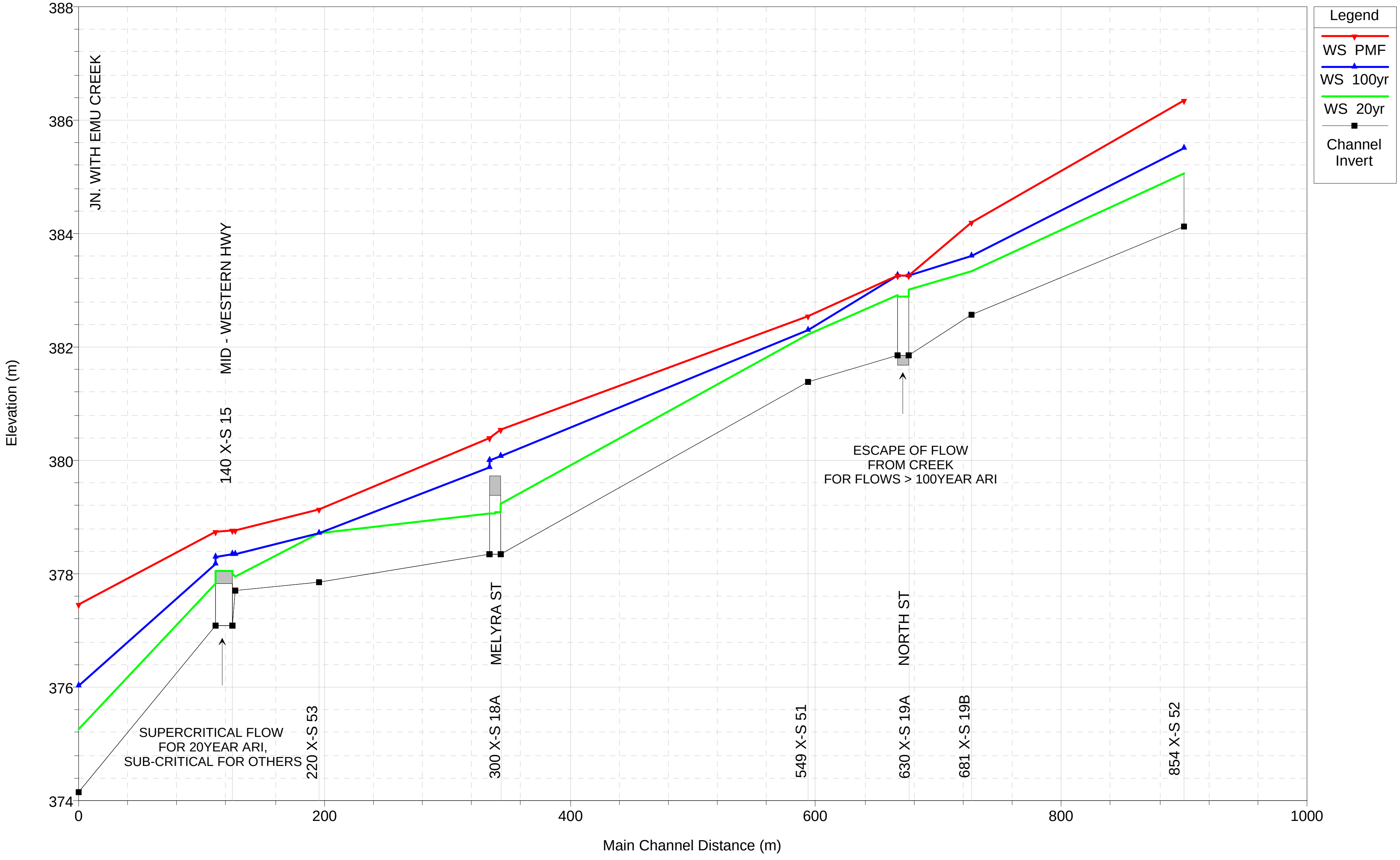
DESIGN WATER SURFACE PROFILES
GOOLOOGONG TRIBUTARY



EMU CREEK FLOOD STUDY

Figure 6.6

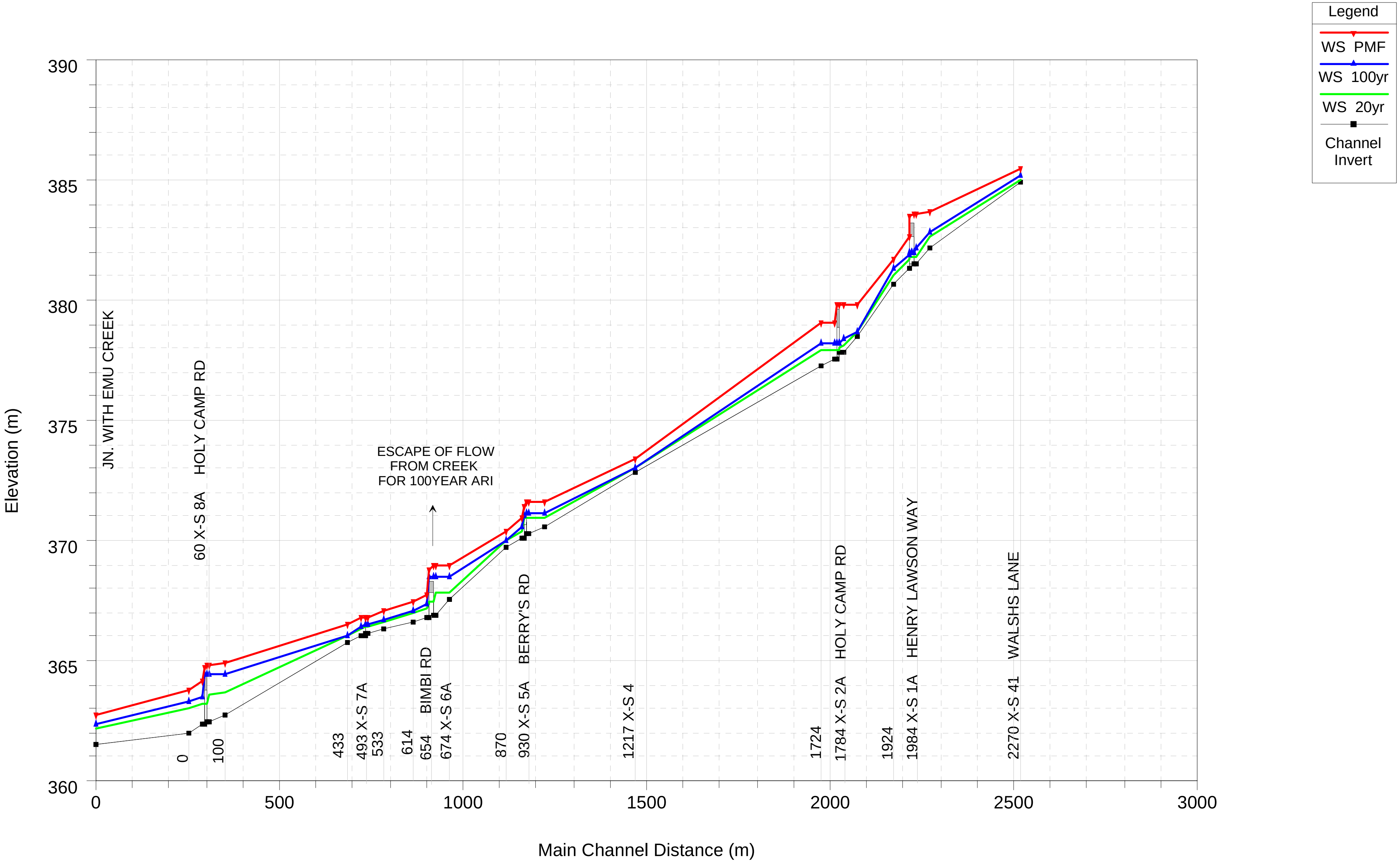
DESIGN WATER SURFACE PROFILES
O'BRIEN TRIBUTARY



EMU CREEK FLOOD STUDY

Figure 6.7

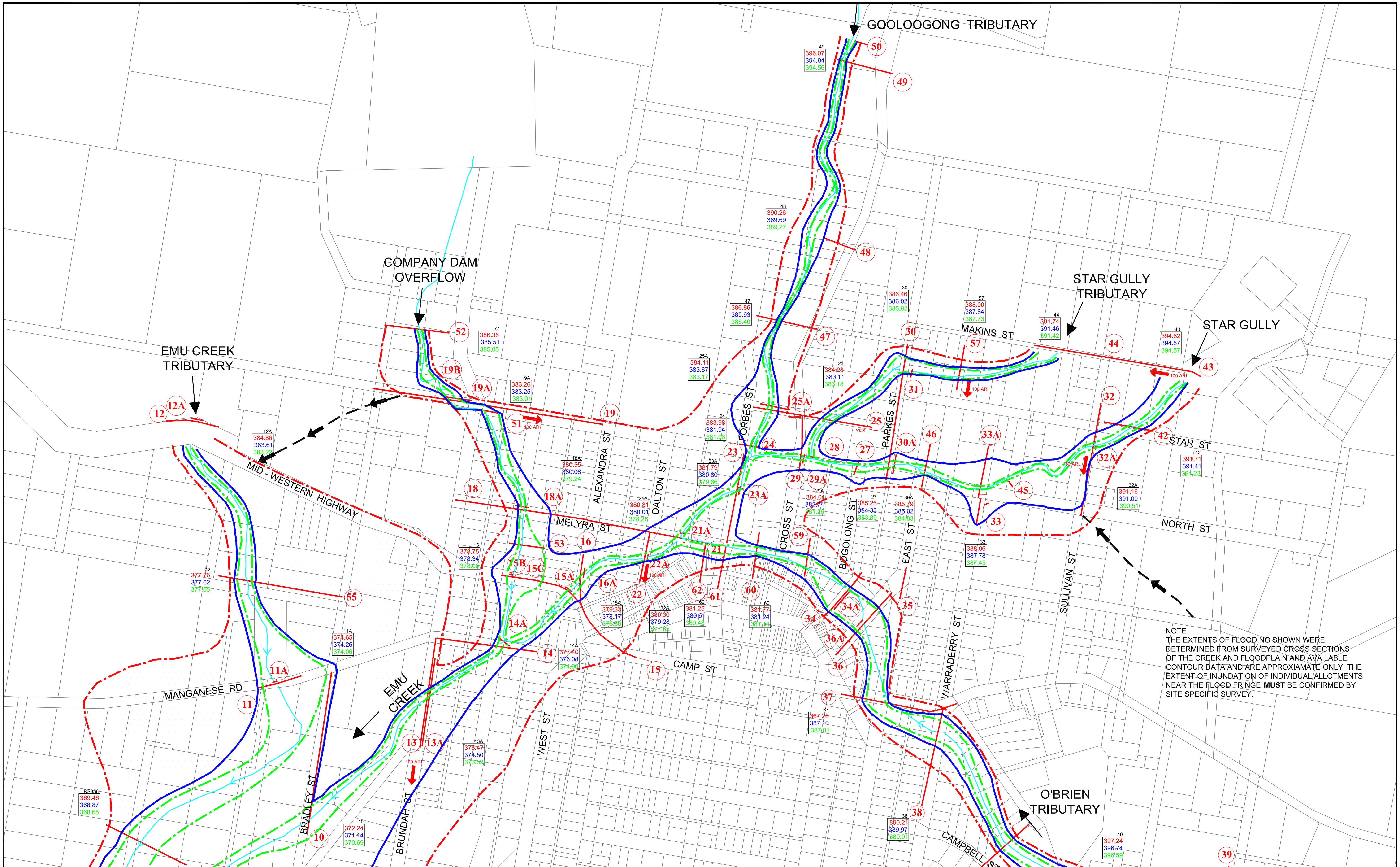
DESIGN WATER SURFACE PROFILES
COMPANY DAM OVERFLOW



EMU CREEK FLOOD STUDY

Figure 6.8

DESIGN WATER SURFACE PROFILES
SOUTHERN TRIBUTARY



N

SCALE

0 200m 400m

LEGEND

INDICATIVE FLOOD EXTENTS

- PMF
- 100 YR.
- 20 YR.

PEAK FLOOD LEVELS

- 18 — CROSS SECTION NO.
- 380.55 — PMF
- 380.08 — 100 YR.
- 379.24 — 20 YR.

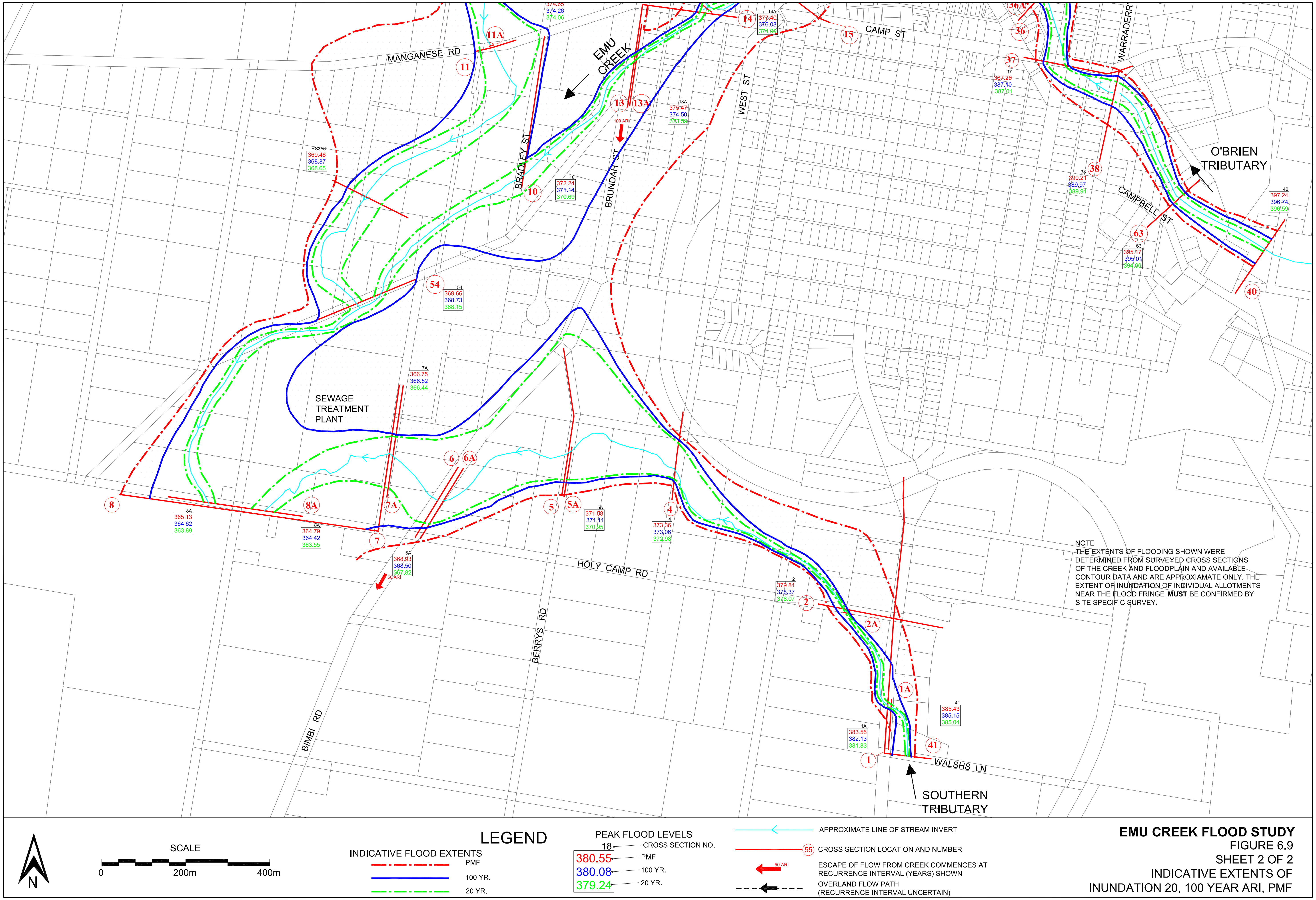
- APPROXIMATE LINE OF STREAM INVERT
- (55) CROSS SECTION LOCATION AND NUMBER
- 50 ARI — ESCAPE OF FLOW FROM CREEK COMMENCES AT RECURRENCE INTERVAL (YEARS) SHOWN
- OVERLAND FLOW PATH (RECURRENCE INTERVAL UNCERTAIN)

EMU CREEK FLOOD STUDY

FIGURE 6.9

SHEET 1 OF 2

INDICATIVE EXTENTS OF INUNDATION 20, 100 YEAR ARI, PMF



EMU CREEK FLOOD STUDY
FIGURE 6.9
SHEET 2 OF 2
INDICATIVE EXTENTS OF INUNDATION 20, 100 YEAR ARI, PMF

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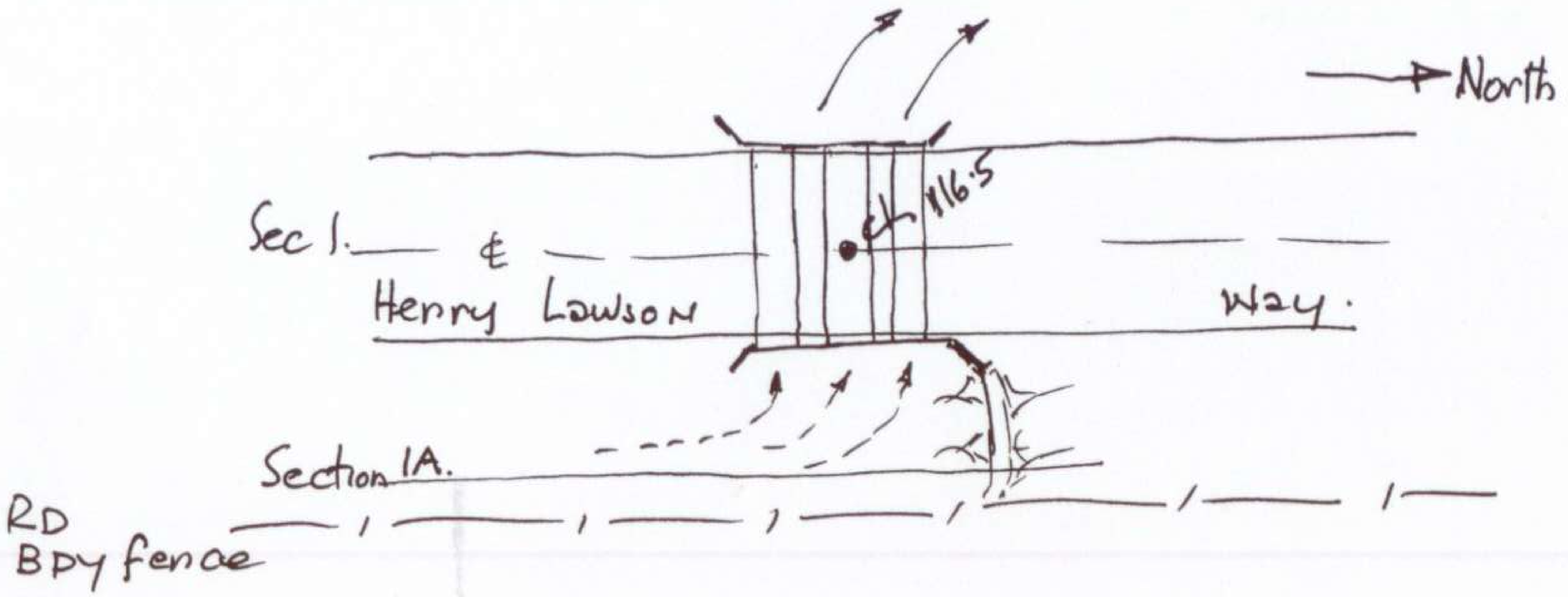
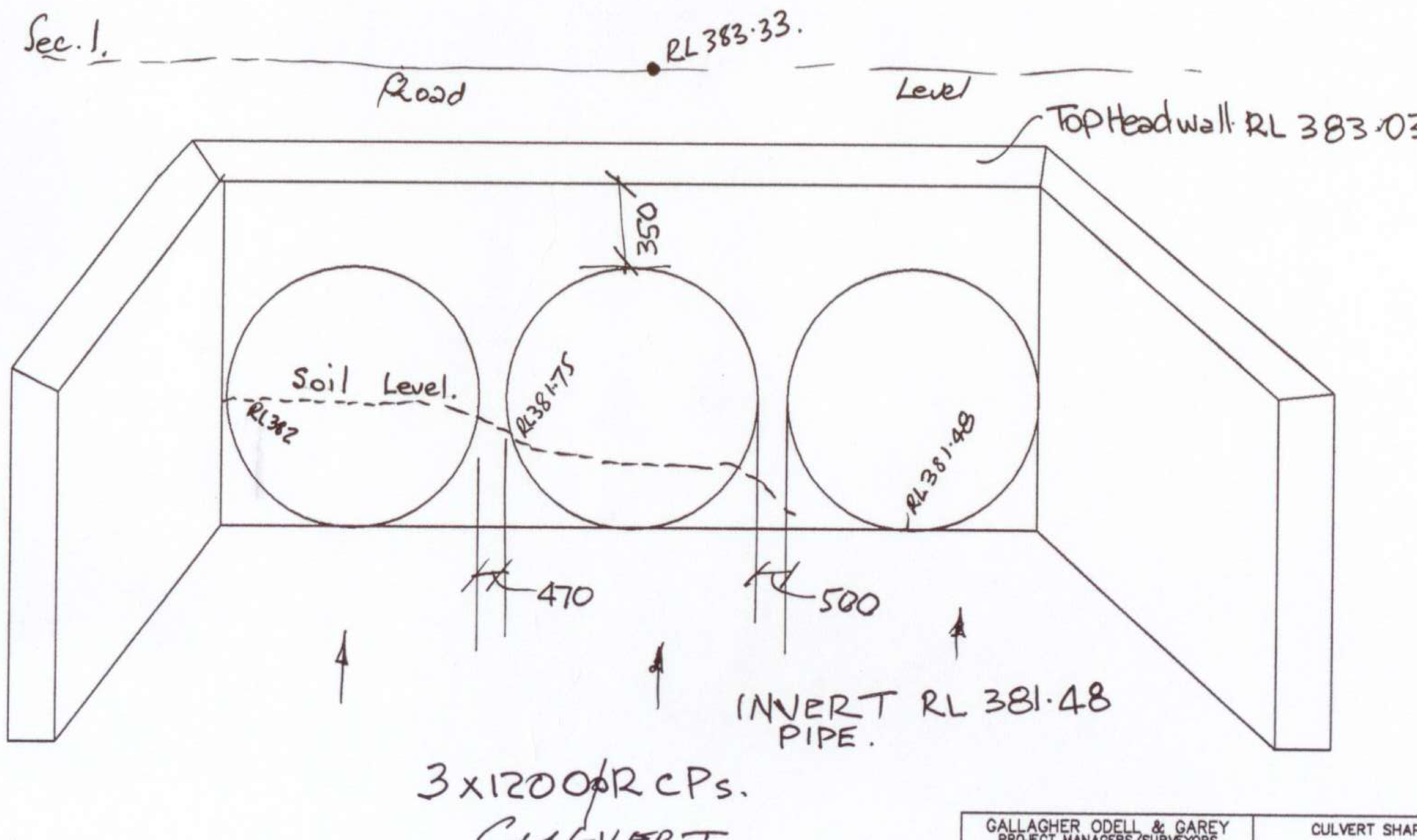
APPENDIX A

SKETCHES OF CULVERTS AND ROAD CROSSINGS IN STUDY AREA

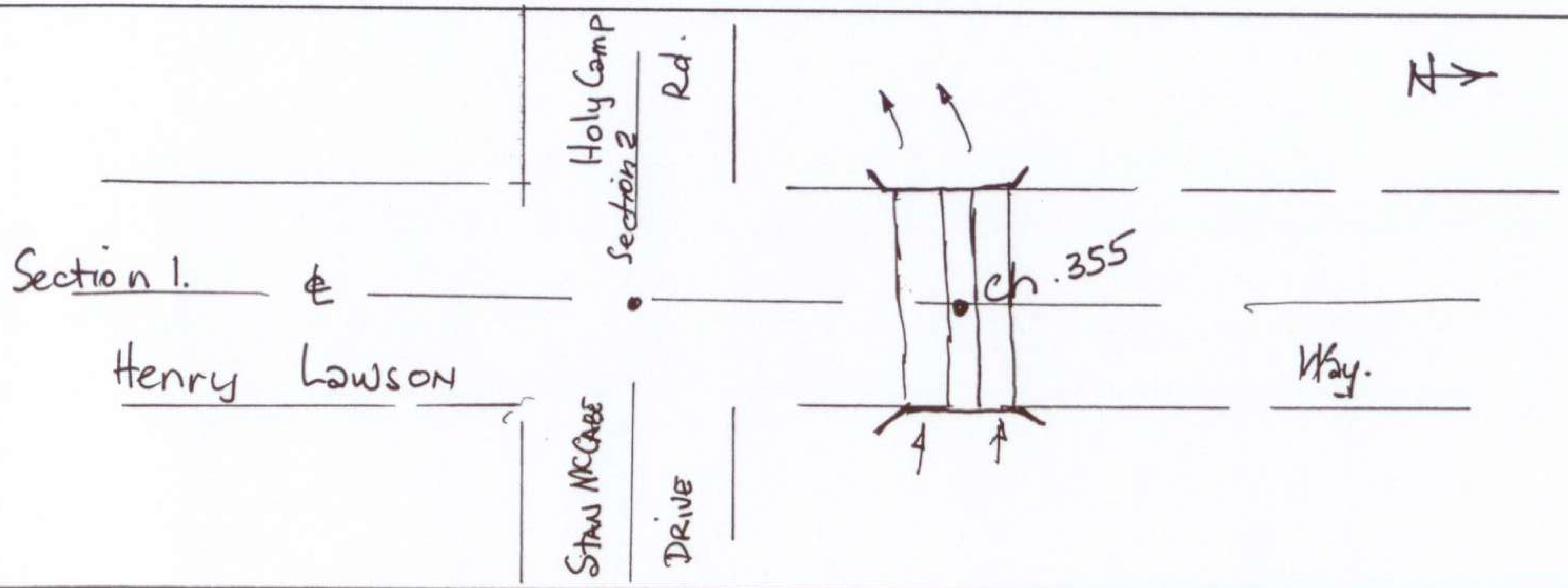
SKETCH 100

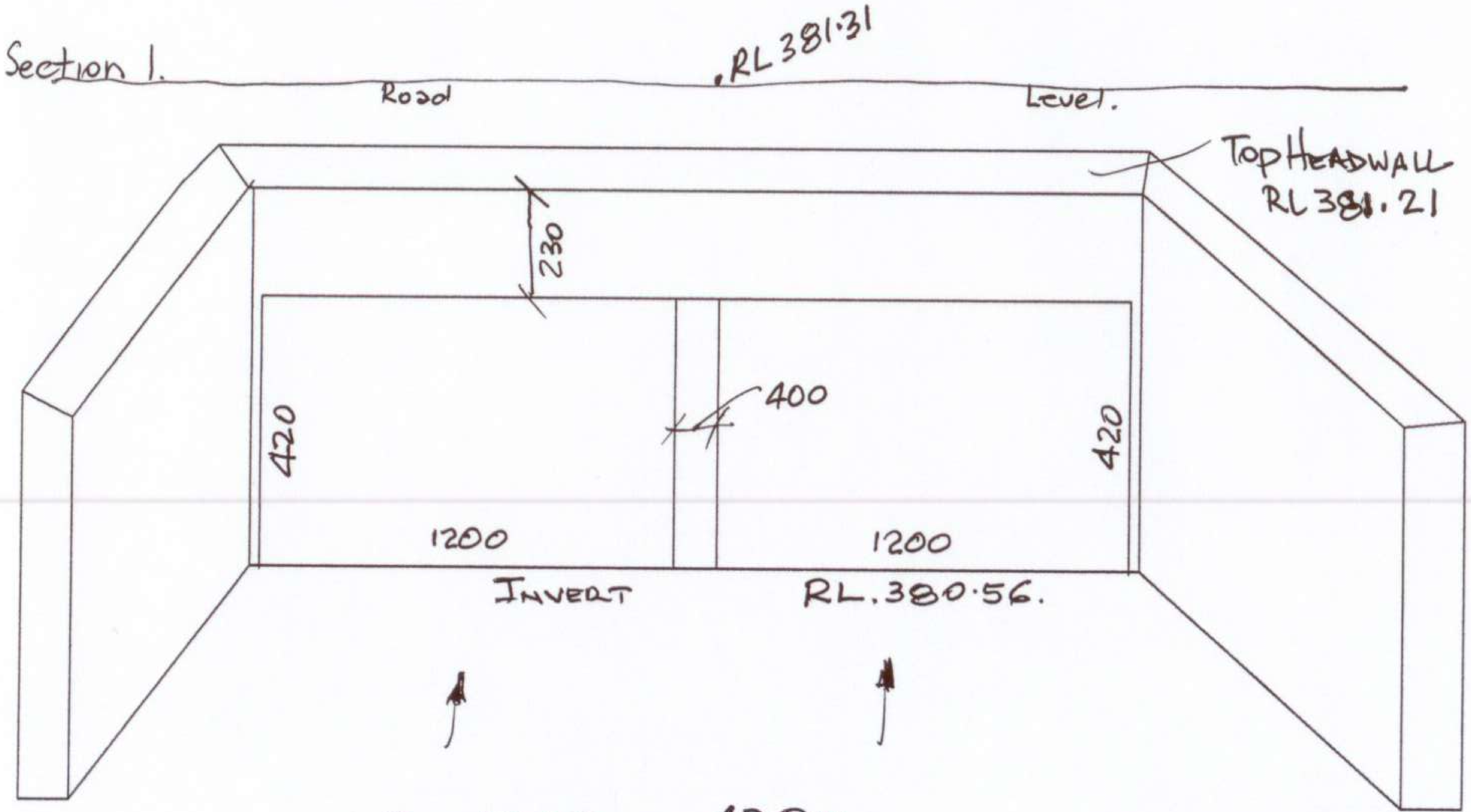




GALLAGHER ODELL & GAREY PROJECT MANAGERS/SURVEYORS GRANNEJOLLA CARGO ROAD ORANGE NSW 2800 PO BOX 2181 ORANGE PHONE 0263 666 175 FAX 0263 666 011	CULVERT SHAPE & DETAIL AT GRENFELL	REFERENCE 9552
DATE: MAY/JUNE 2005 — SCALE:	SHIRE OF WEDDIN	SHEET OF

SKETCH 101

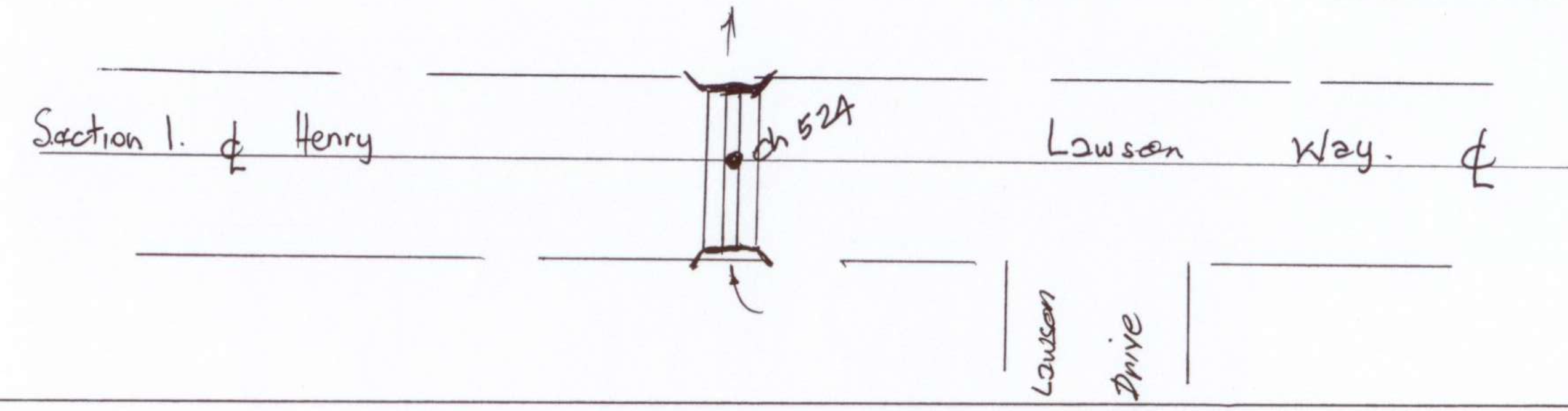


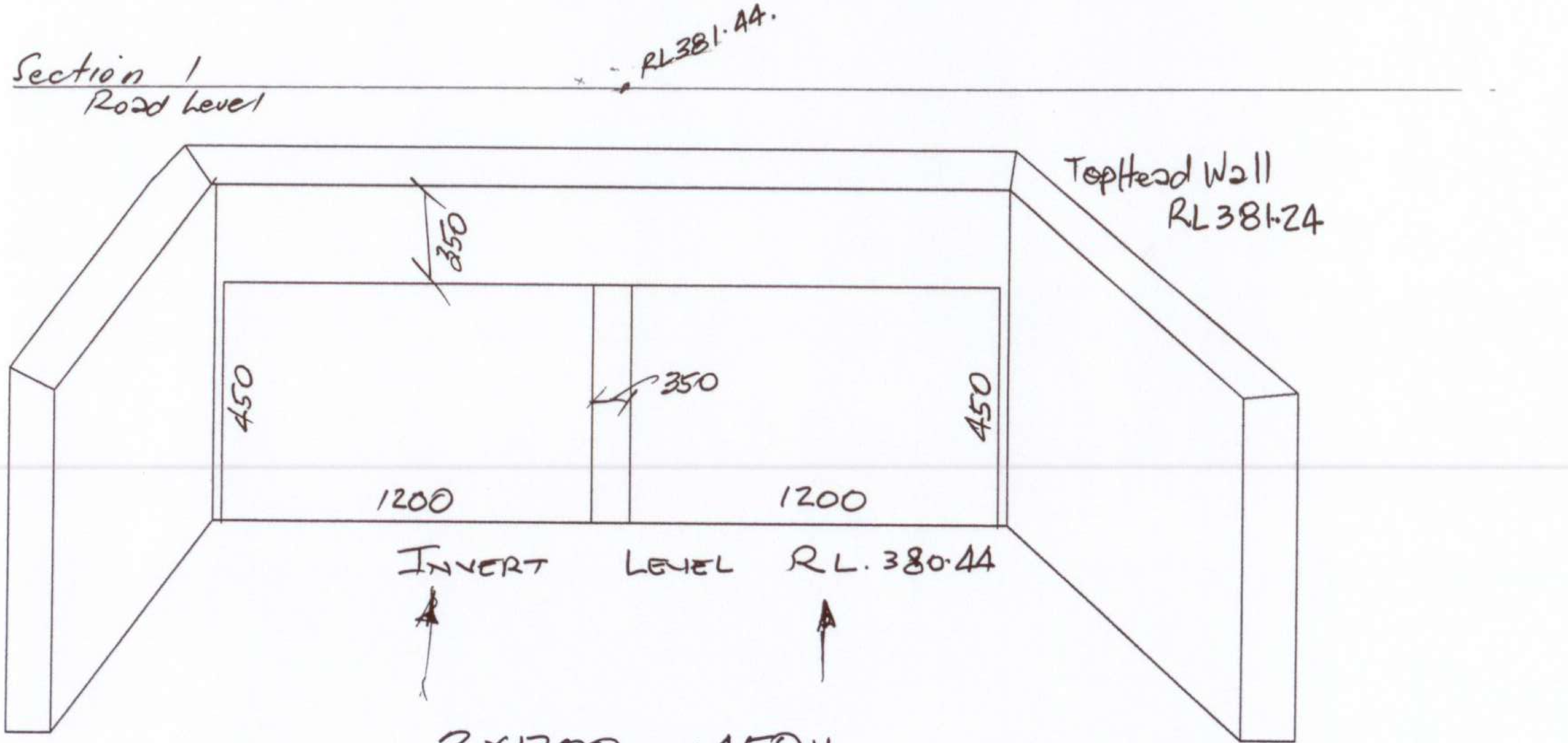


2 x 1200W x 420H
CONC. BOX CULVERTS.

GALLAGHER ODELL & GAREY PROJECT MANAGERS/SURVEYORS	CULVERT SHAPE & DETAIL AT GRENFELL	REFERENCE 9552
DATE MAY/JUNE 2006 — SCALE	SHIRE OF WEDDIN	SHEET OF

SKETCH 102

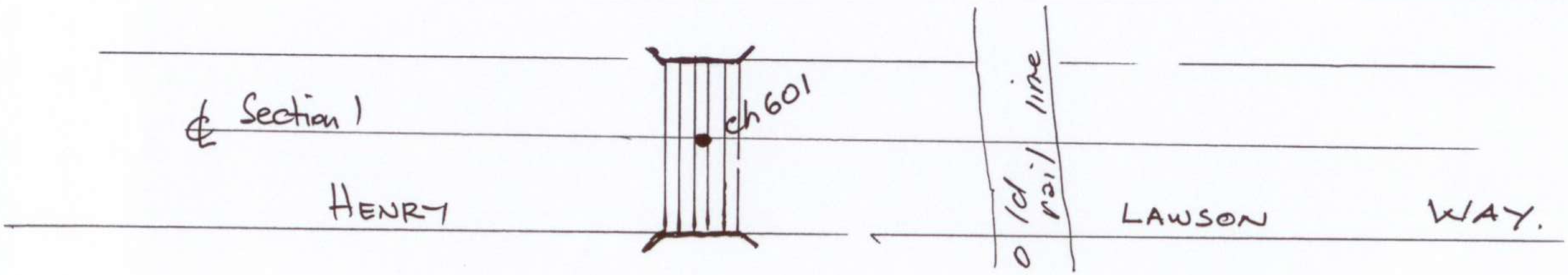


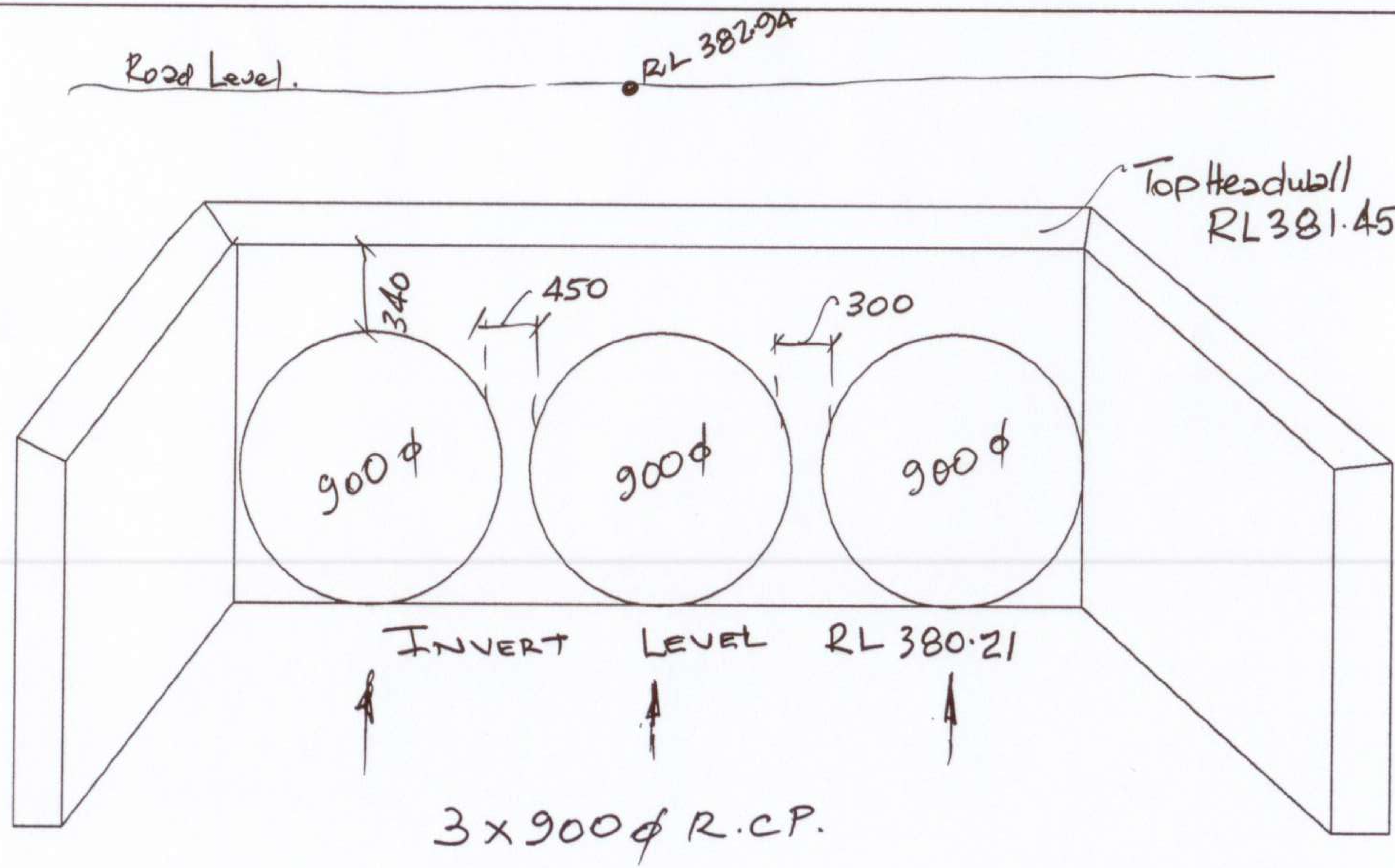


2 x 1200 w x 450 H
CONC. BOX CULVERTS.

GALLAGHER ODELL & GAREY PROJECT MANAGERS/SURVEYORS GRAHAMS DELLA CARGO ROAD ORANGE NSW 2800 PO BOX 3191 ORANGE PHONE: 0263 666 175 FAX: 0263 666 011	CULVERT SHAPE & DETAIL AT GRENFELL	REFERENCE 9552
DATE: MAY/JUNE 2005 SCALE:	SHIRE OF WEDDIN	SHEET OF

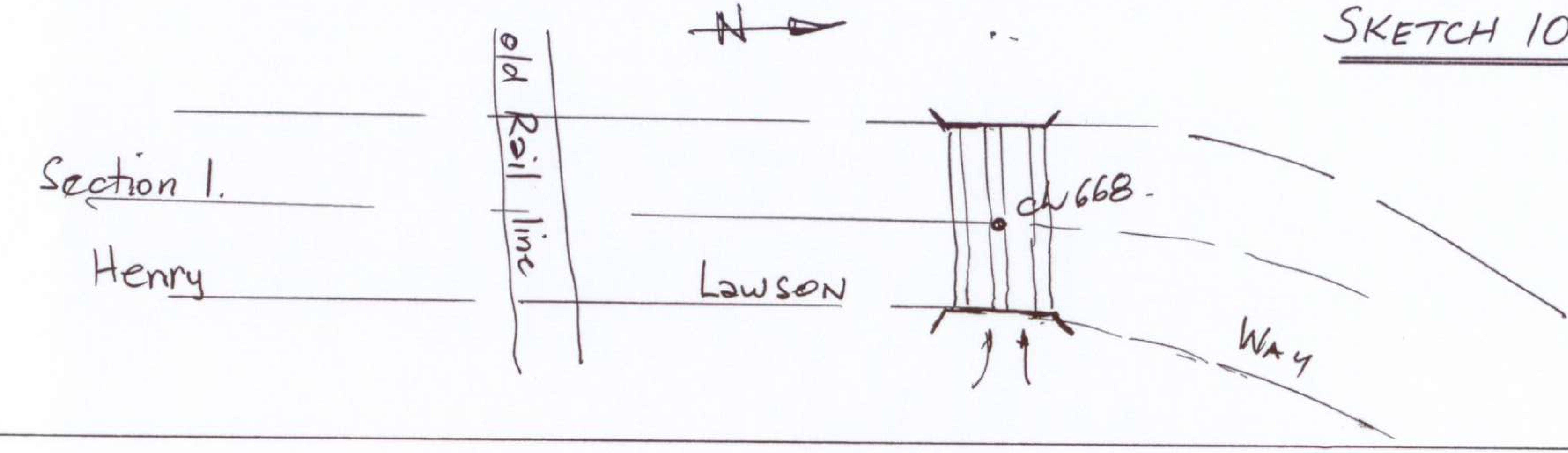
SKETCH 103

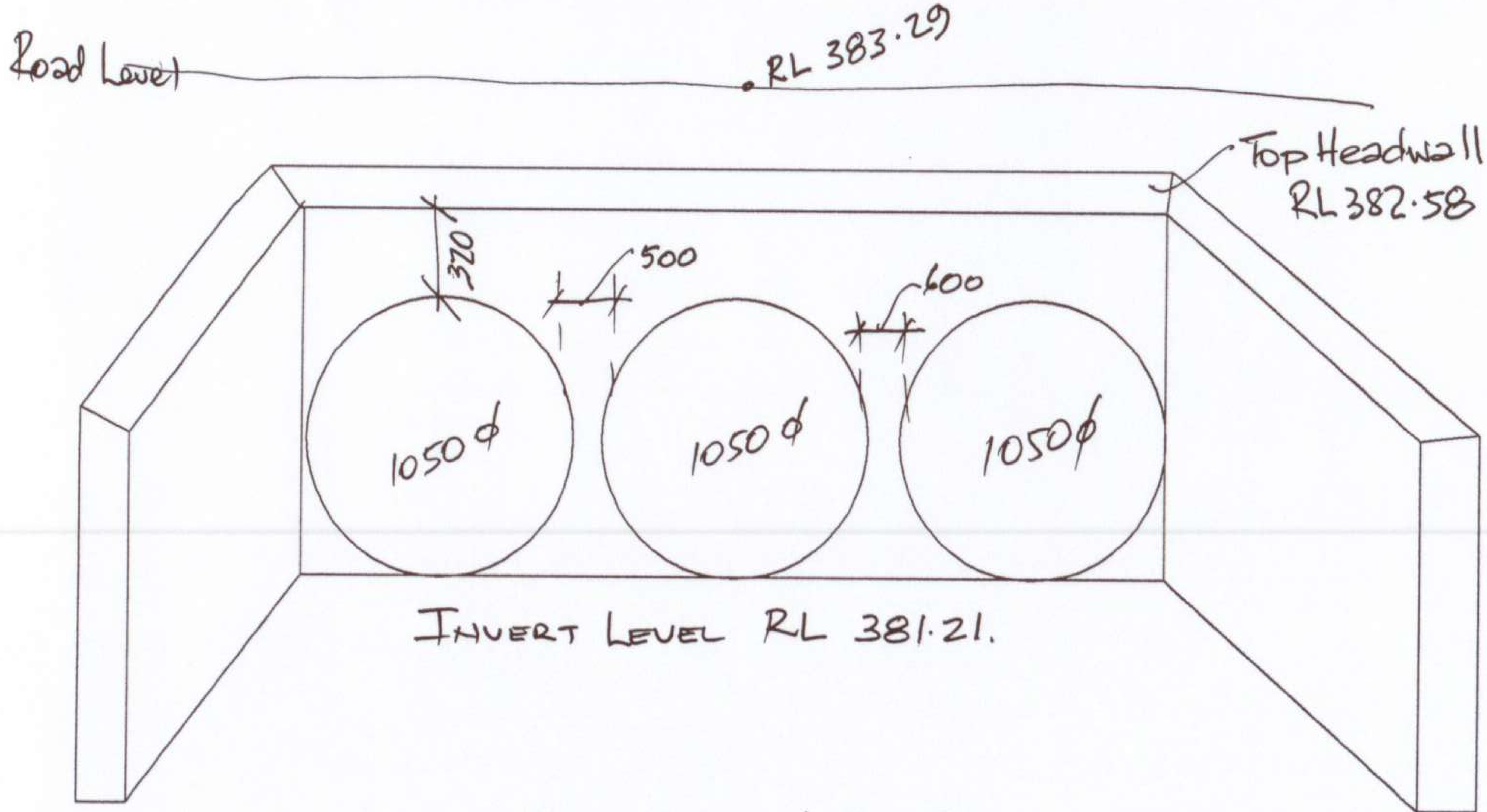




GALLAGHER ODELL & GAREY PROJECT MANAGERS/SURVEYORS CARGO ROAD ORANGE NSW	CULVERT SHAPE & DETAIL AT GRENFELL	REFERENCE 9552
DATE MAY/JUNE 2005 — SCALE	SHIRE OF WEDDIN	SHEET OF

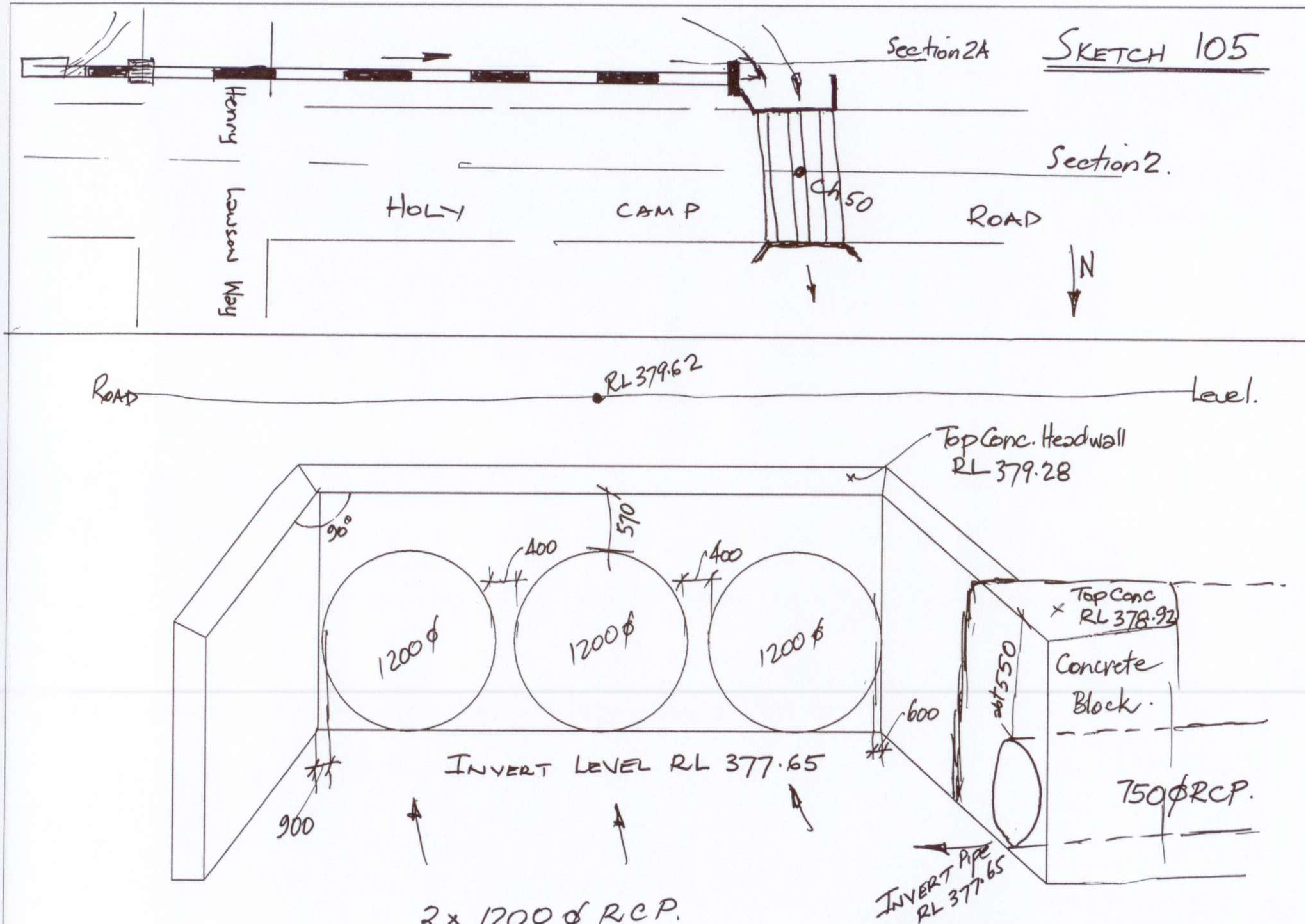
SKETCH 104





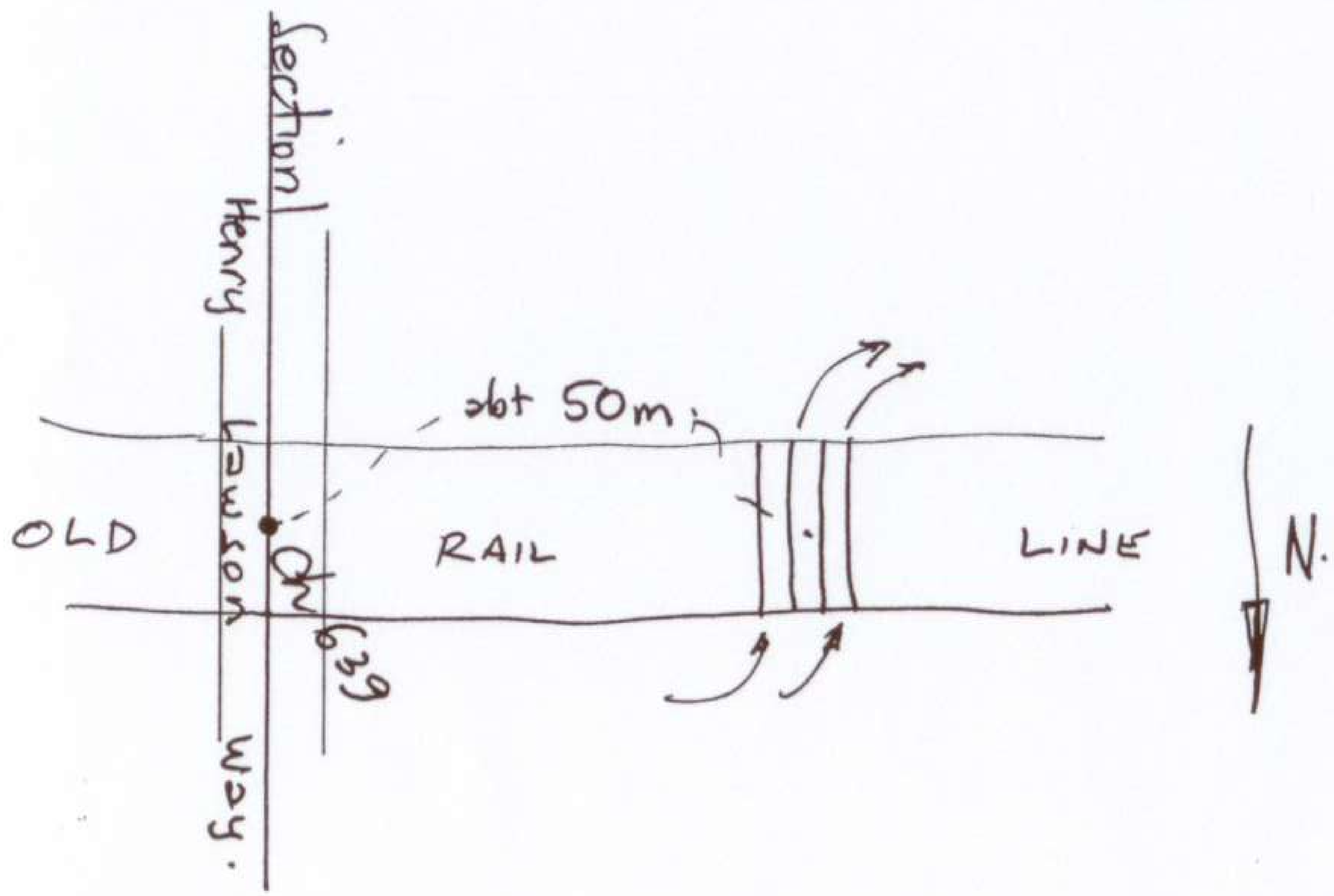
3 X 1050 ϕ RCP.

GALLAGHER ODELL & GAREY PROJECT MANAGERS/SURVEYORS	CULVERT SHAPE & DETAIL AT GRENFELL	REFERENCE 9552
DATE MAY/JUNE 2005 — SCALE:	SHIRE OF WEDDIN	SHEET OF

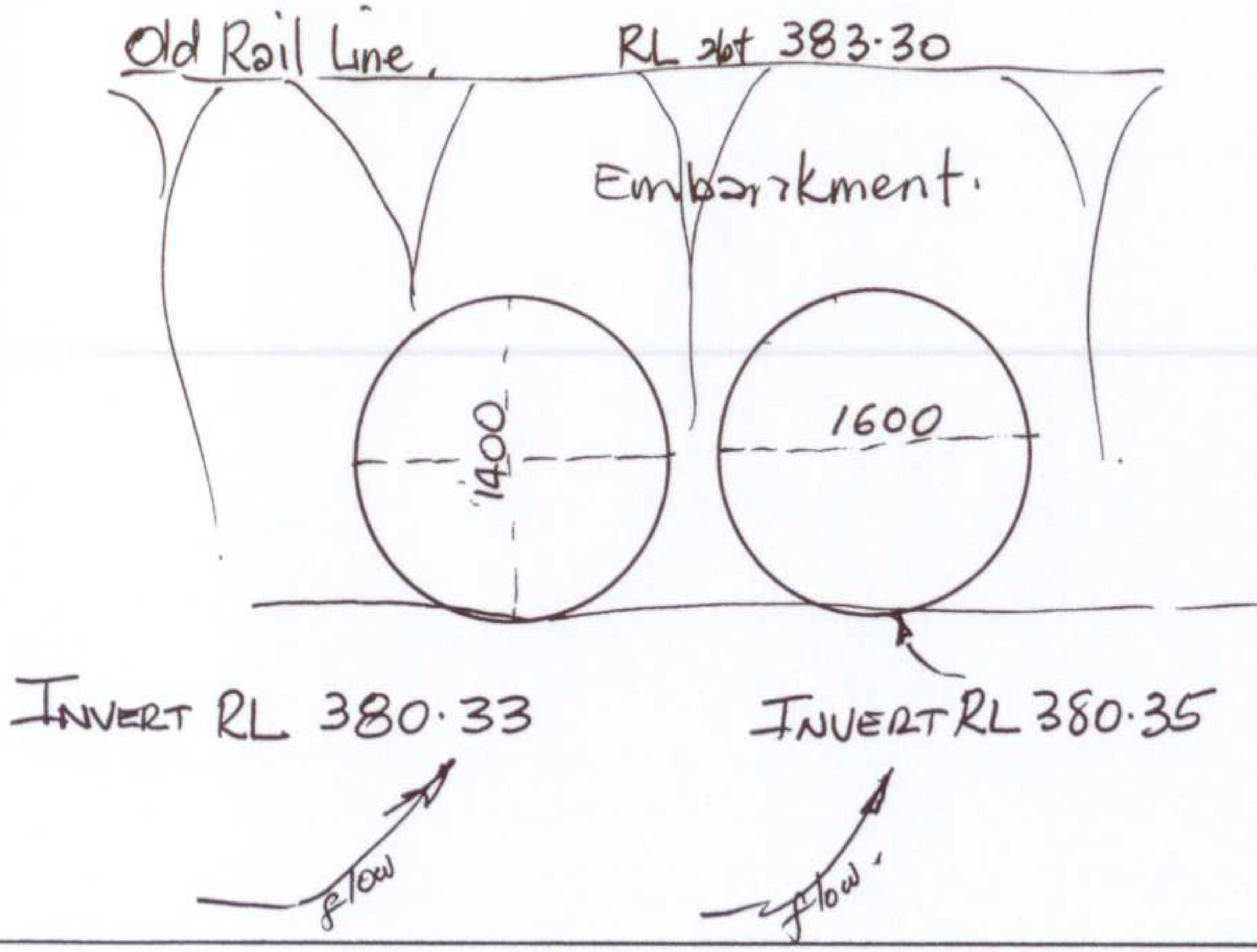


GALLAGHER ODELL & GAREY PROJECT MANAGERS/SURVEYORS CARGO ROAD ORANGE NSW 2800 PO BOX 2151 ORANGE	CULVERT SHAPE & DETAIL AT GRENFELL	REFERENCE 9552
DATED MAY/JUNE 2005	SCALE	
	SHIRE OF WEDDIN	SHEET OF

SKETCH 106.



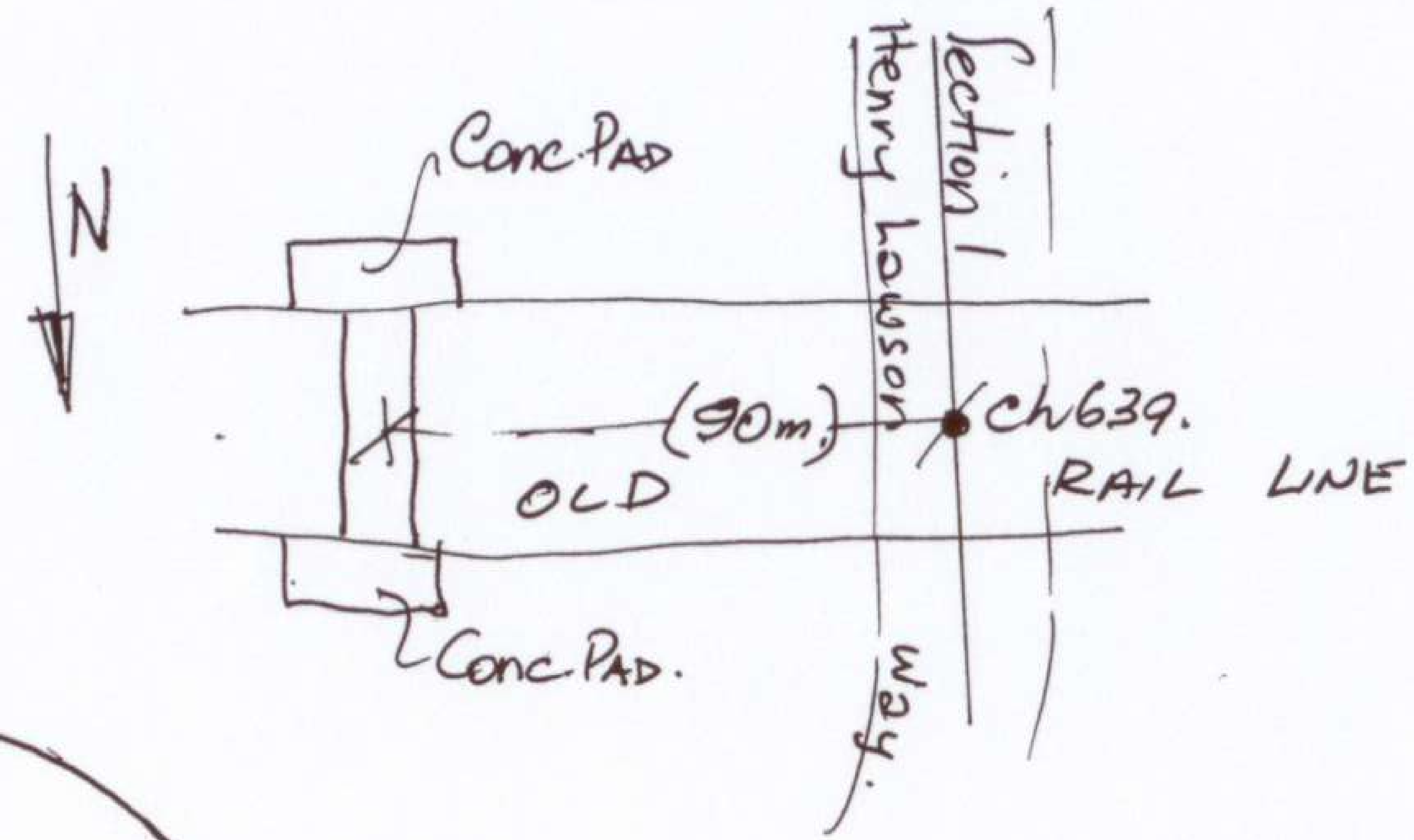
CULVERT C106



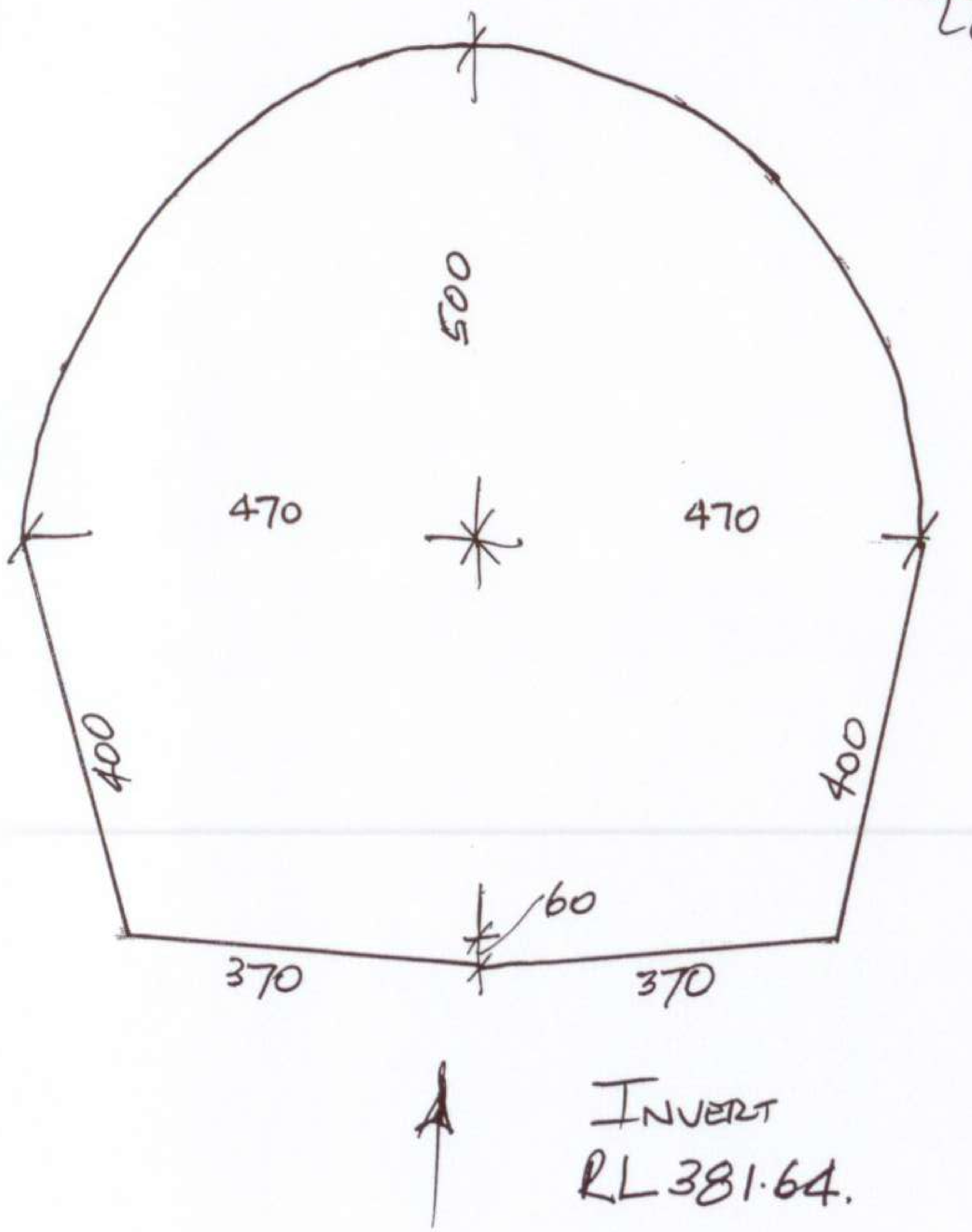
2 x ARMCO CULVERTS.
1400 High ϕ, 1600 Wide ϕ.
(Probably 1500ϕ but pushed out of shape)

GALLAGHER ODELL & GAREY PROJECT MANAGERS/SURVEYORS GRAMMERCELLA CARGO ROAD ORANGE NSW 2800 PO BOX 3151 ORANGE PHONE 02 6363 1755 FAX 02 6363 1011	CULVERT SHAPE & DETAIL AT GRENFELL	REFERENCE 9552
DATE: MAY/JUNE 2006 SCALE:	SHIRE OF WEDDIN	SHEET OF

SKETCH 107



CULVERT C107



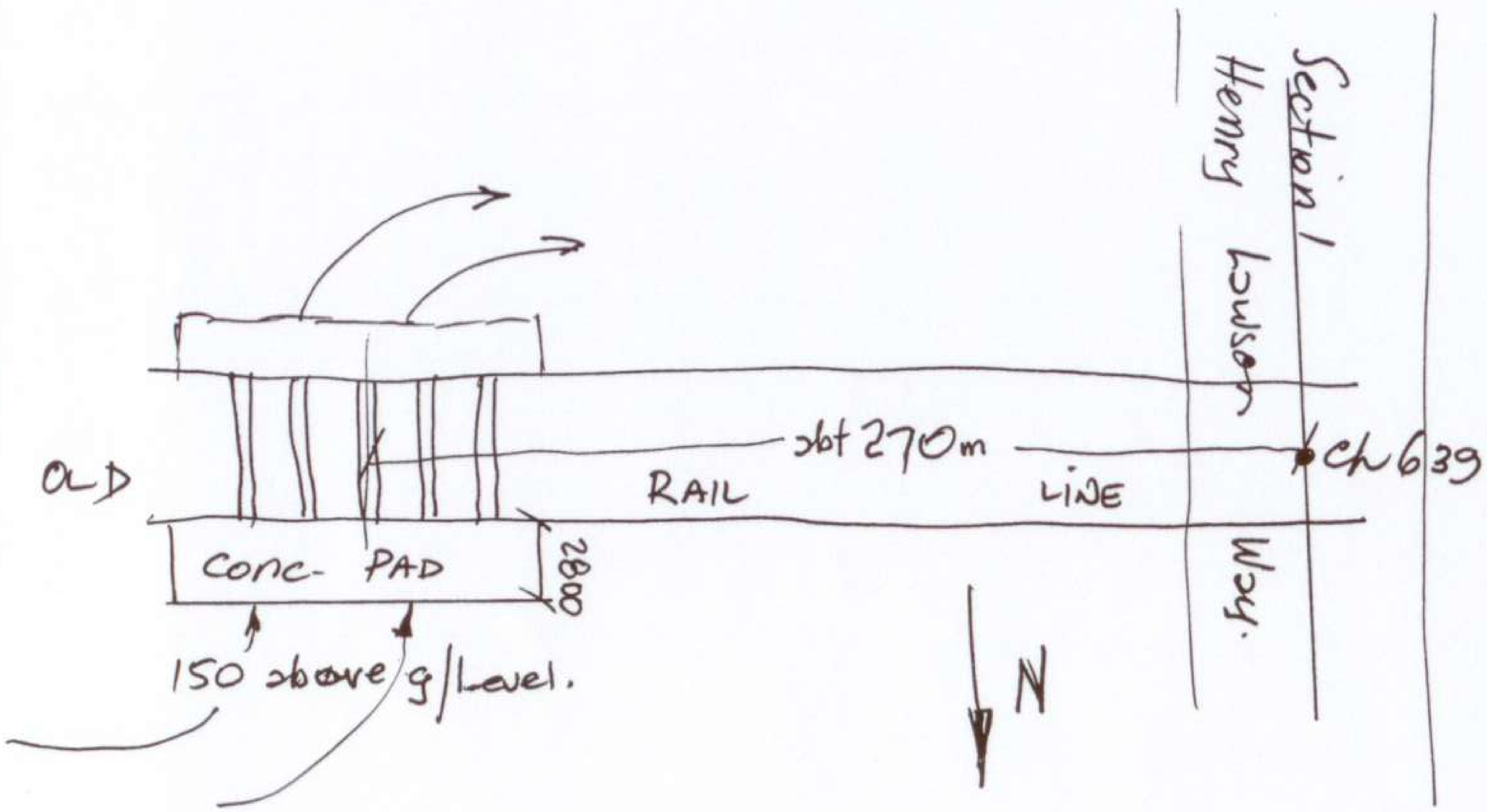
BRICK CULVERT.

0.73 m^2 Cross Sectional Area.

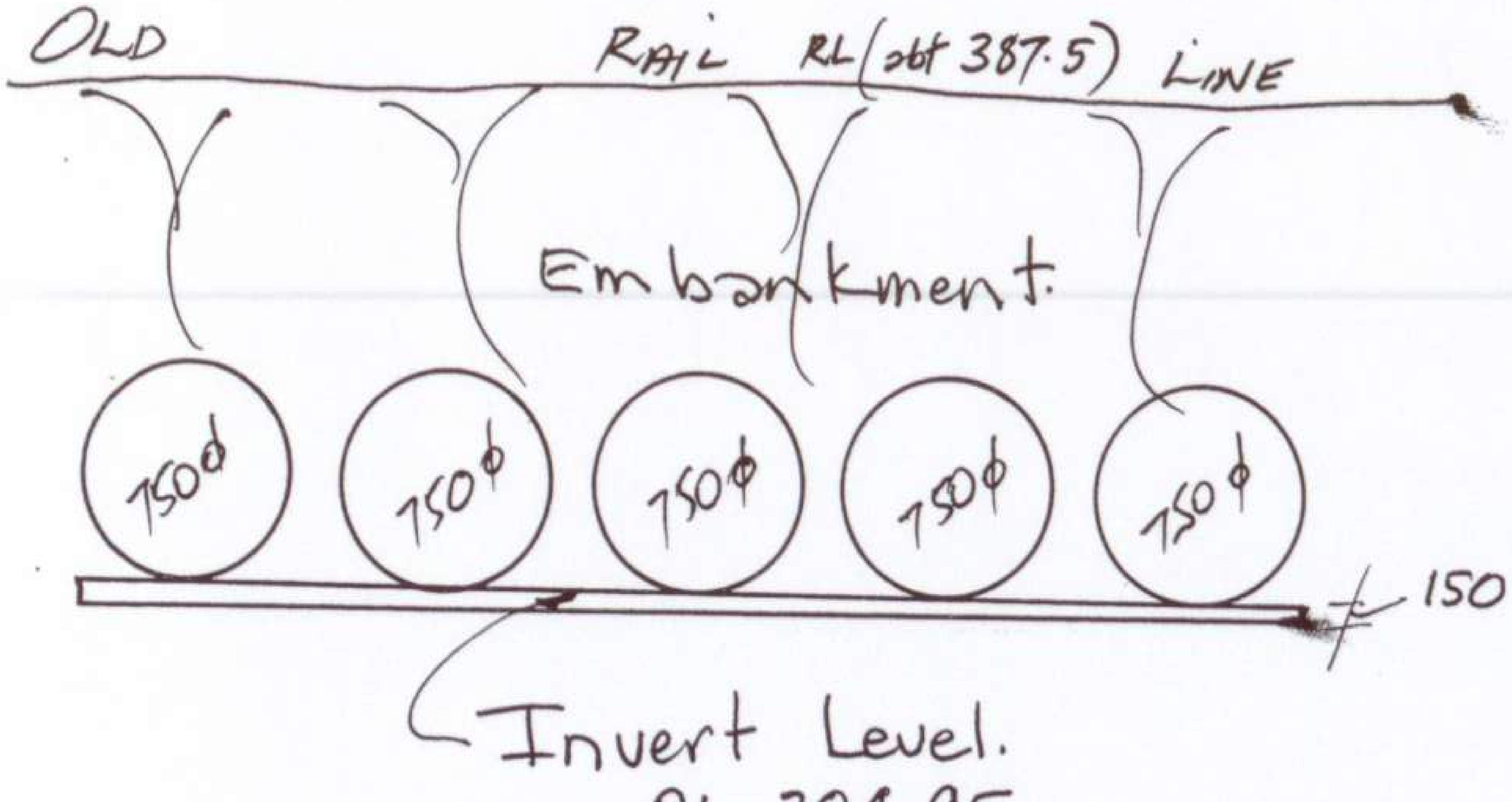
INVERT
RL 381.64.

GALLAGHER ODELL & GAREY PROJECT MANAGERS/SURVEYORS	CULVERT SHAPE & DETAIL AT GRENFELL	REFERENCE 9552
DATE: MAY/JUNE 2005	SHIRE OF WEDDIN	SHEET OF

SKETCH 108.



CULVERT
C108



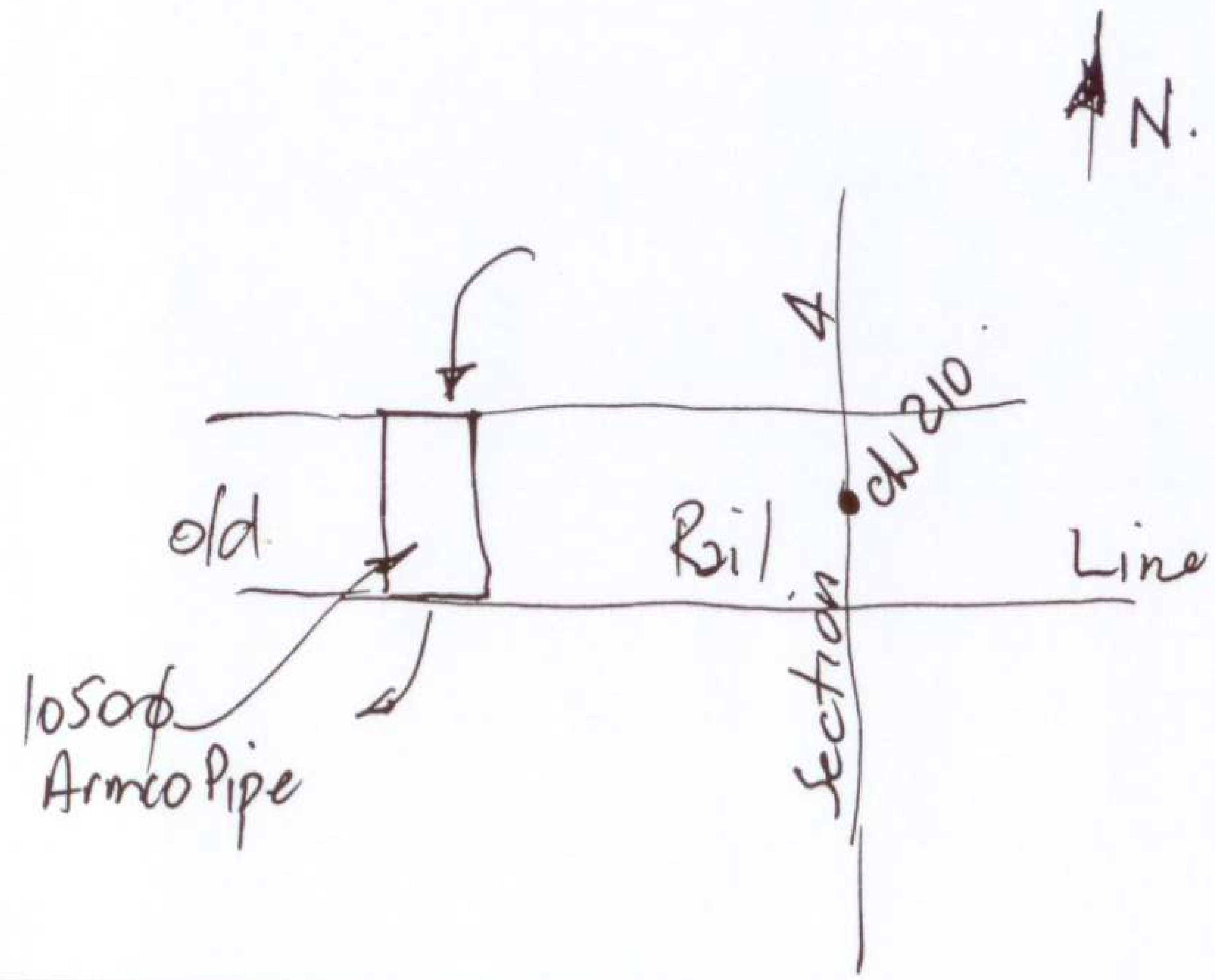
5 X 750φ Armco Pipes.
(with concrete apron.)

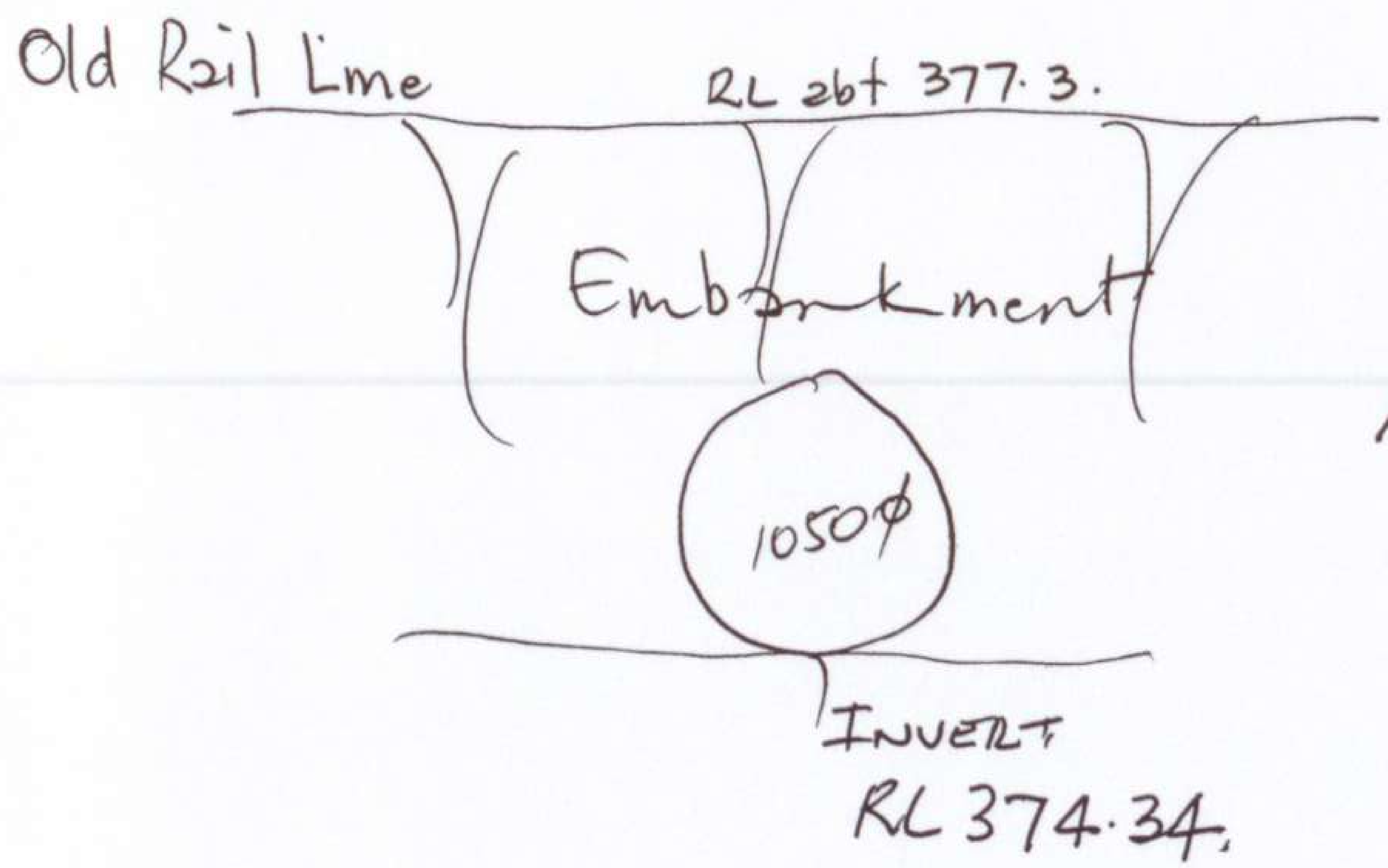
Water up to 150mm in depth by passes the culvert.

GALLAGHER ODELL & GAREY PROJECT MANAGERS/SURVEYORS GRANGEWELLA CARGO ROAD ORANGE NSW 2800 PO BOX 3151 ORANGE	CULVERT SHAPE & DETAIL AT GRENFELL	REFERENCE 9552
DATE MAY/JUNE 2005 SCALE	SHIRE OF WEDDIN	SHEET OF

SKETCH 109

CULVERT C109

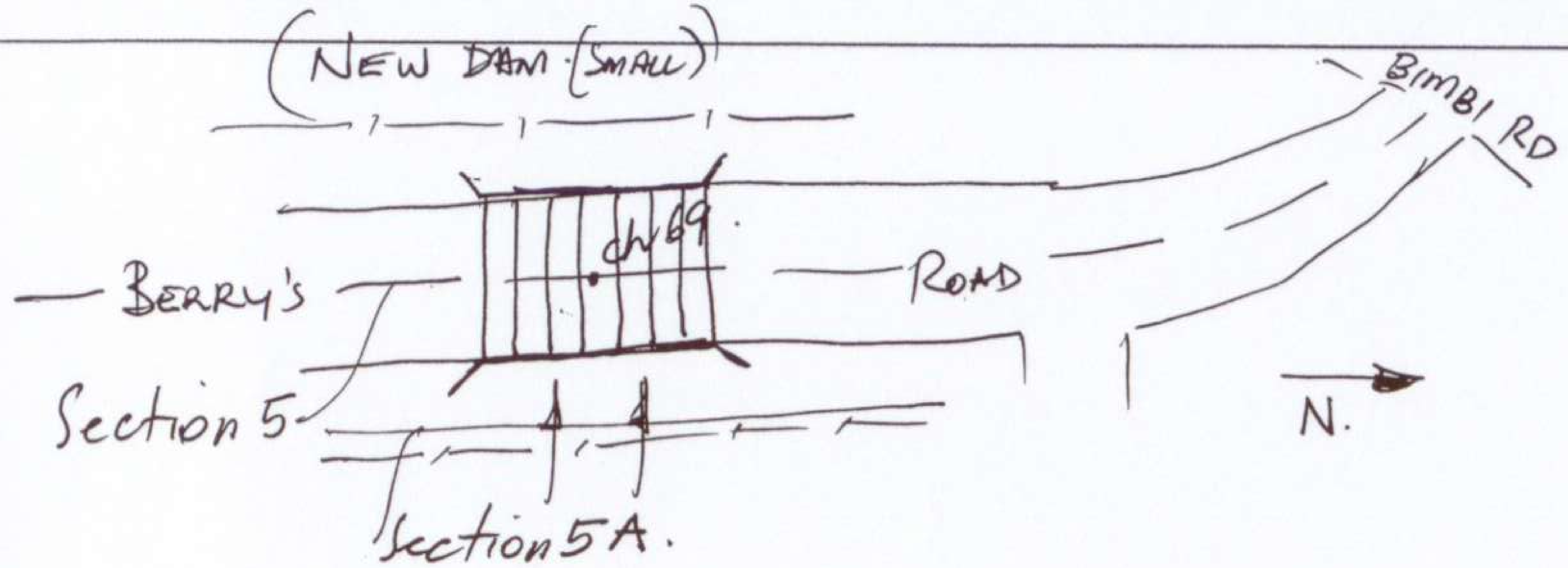


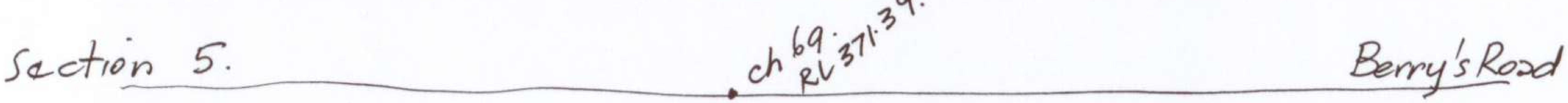


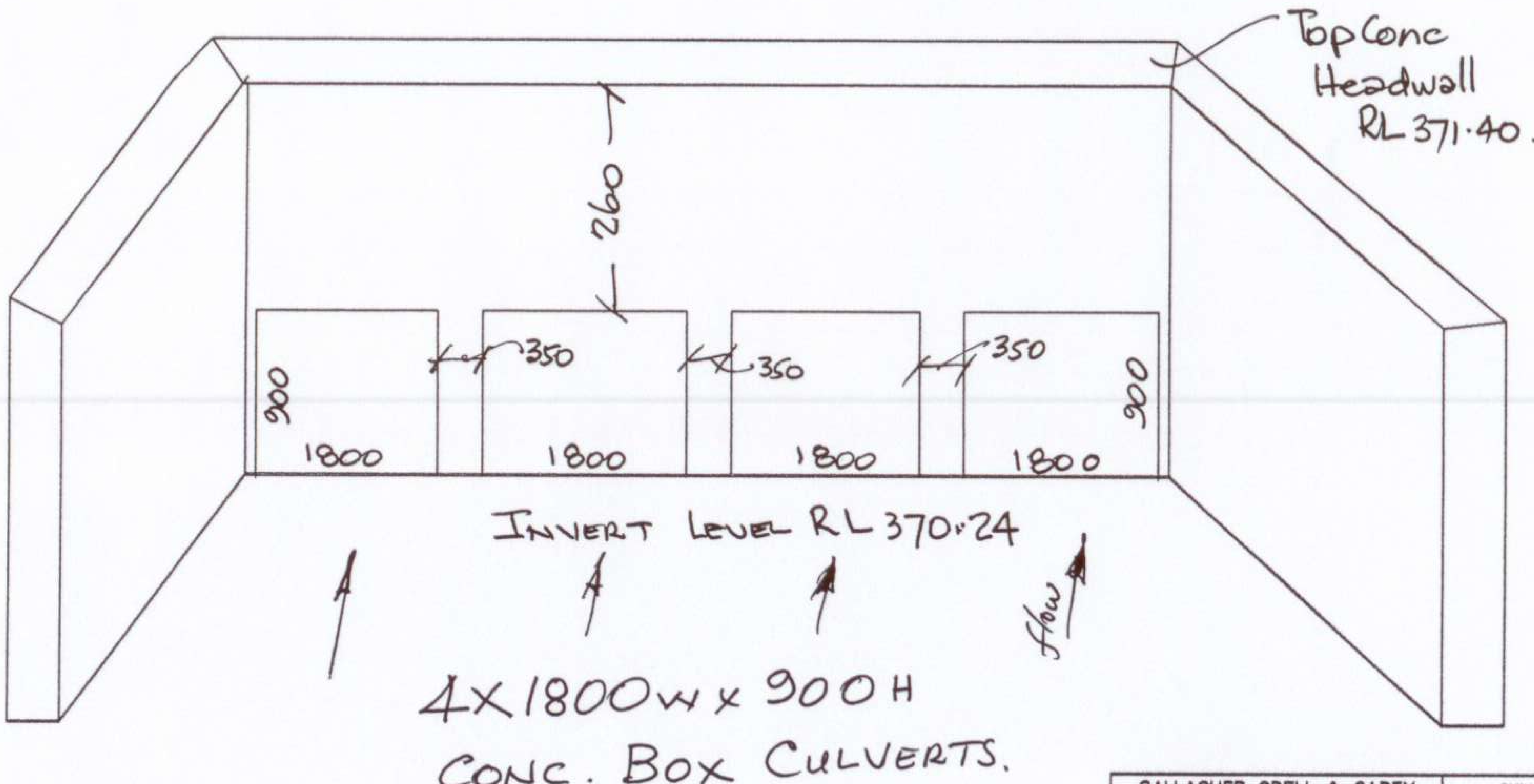
1050 ϕ Armco Pipe

GALLAGHER ODELL & GAREY PROJECT MANAGERS/SURVEYORS	CULVERT SHAPE & DETAIL AT GRENFELL	REFERENCE 9552
DATE MAY/JUNE 2005 SCALE	SHIRE OF WEDDIN	SHEET OF

SKETCH 110.

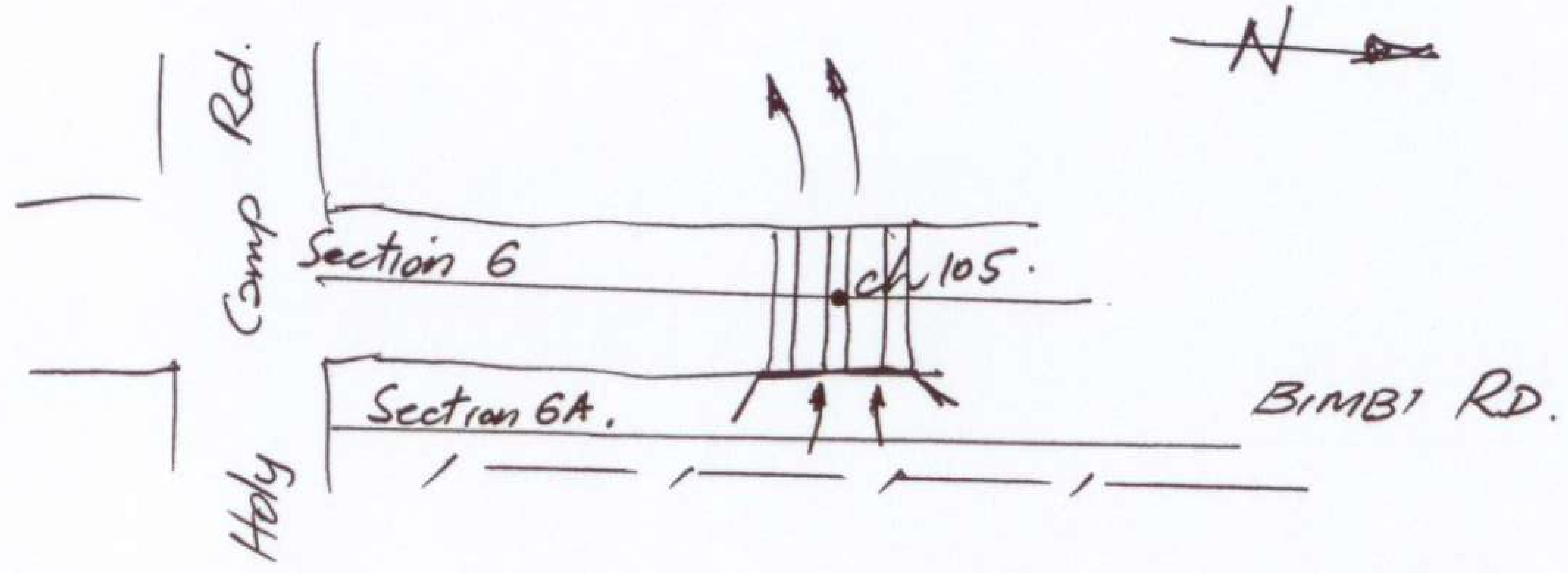


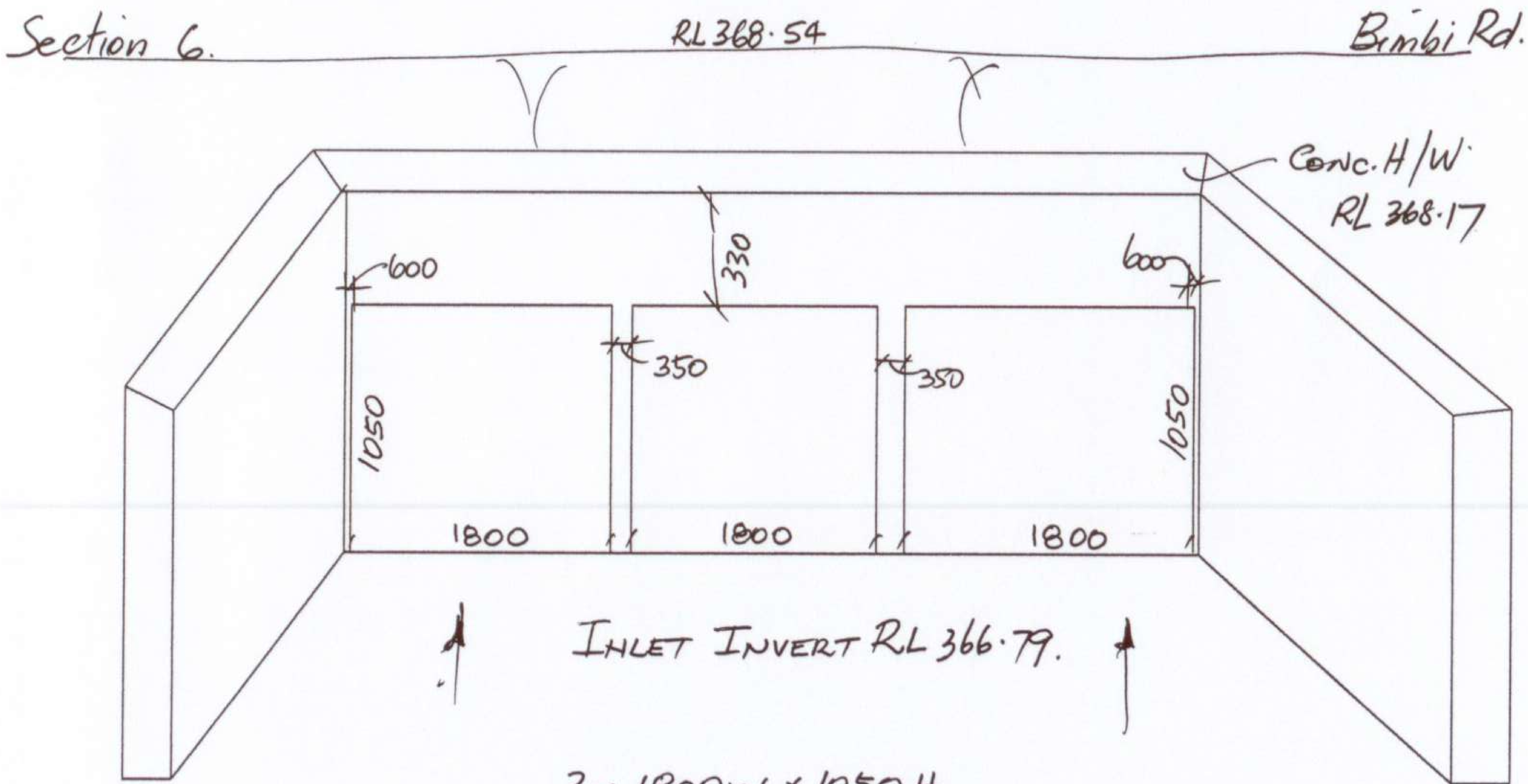




GALLAGHER ODELL & GAREY PROJECT MANAGERS/SURVEYORS	CULVERT SHAPE & DETAIL AT GRENFELL	REFERENCE 9552
DATE MAY/JUNE 2005 · SCALE	SHIRE OF WEDDIN	SHEET OF

SKETCH 111

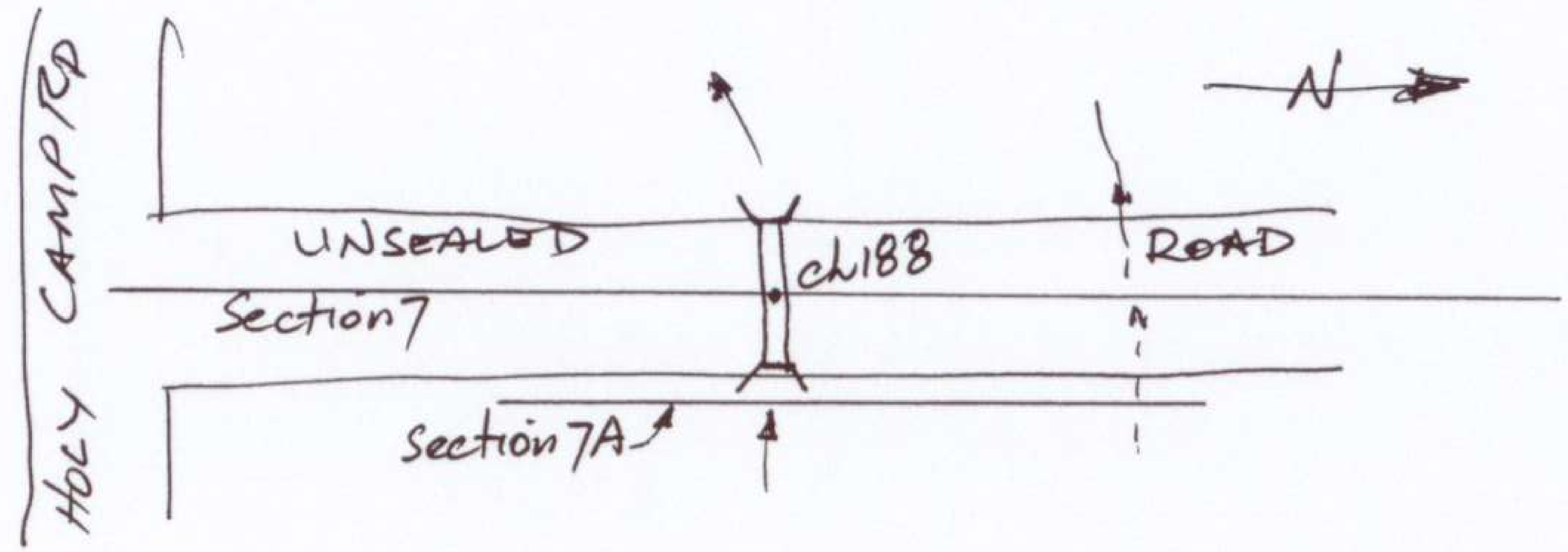


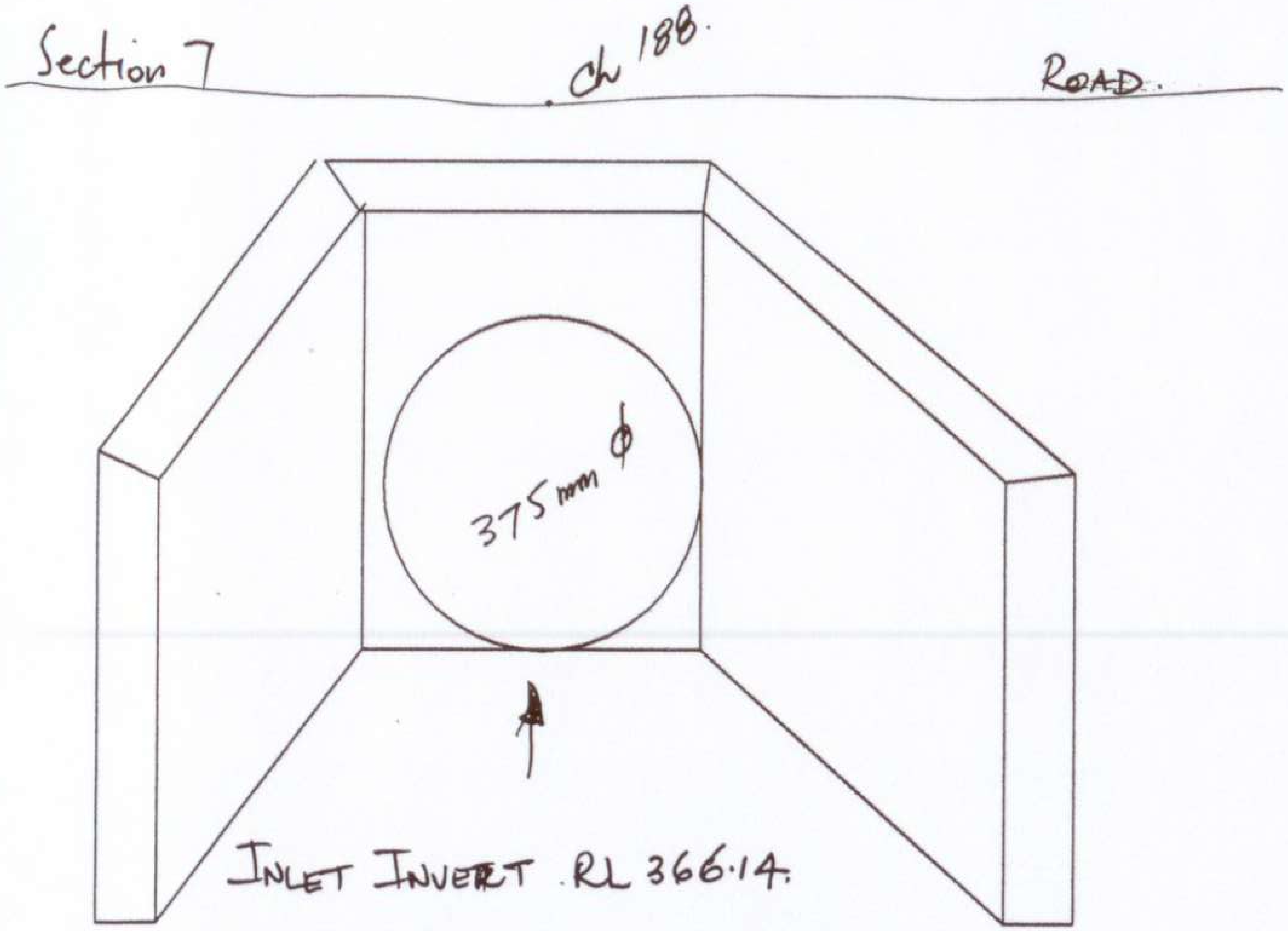


3x 1800W x 1050H
CONC. BOX CULVERTS.

GALLAGHER ODELL & GAREY PROJECT MANAGERS/SURVEYORS	CULVERT SHAPE & DETAIL AT GRENFELL	REFERENCE 9552
DATE MAY/JUNE 2006 / SCALE	SHIRE OF WEDDIN	SHEET OF

SKETCH 112

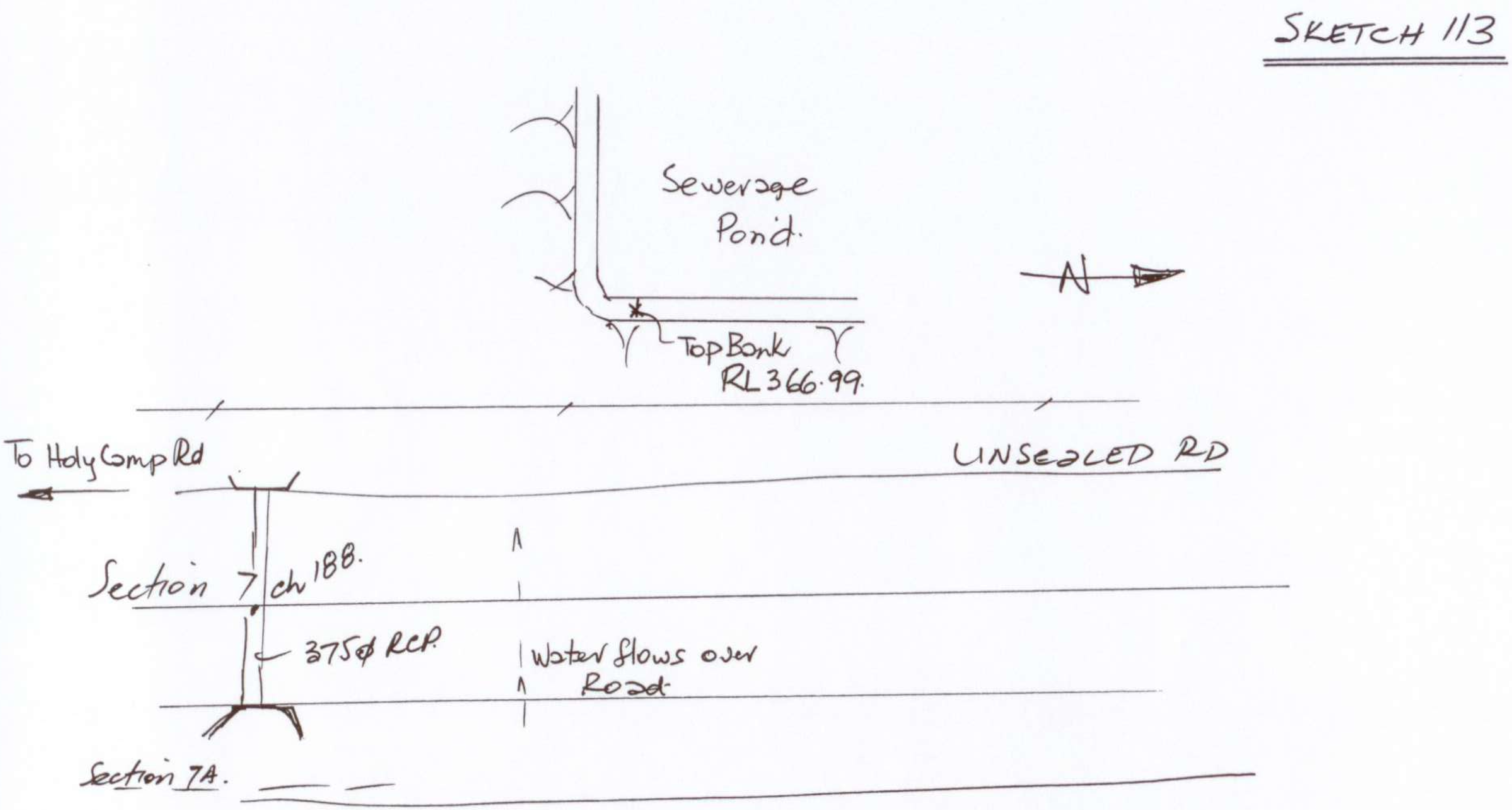




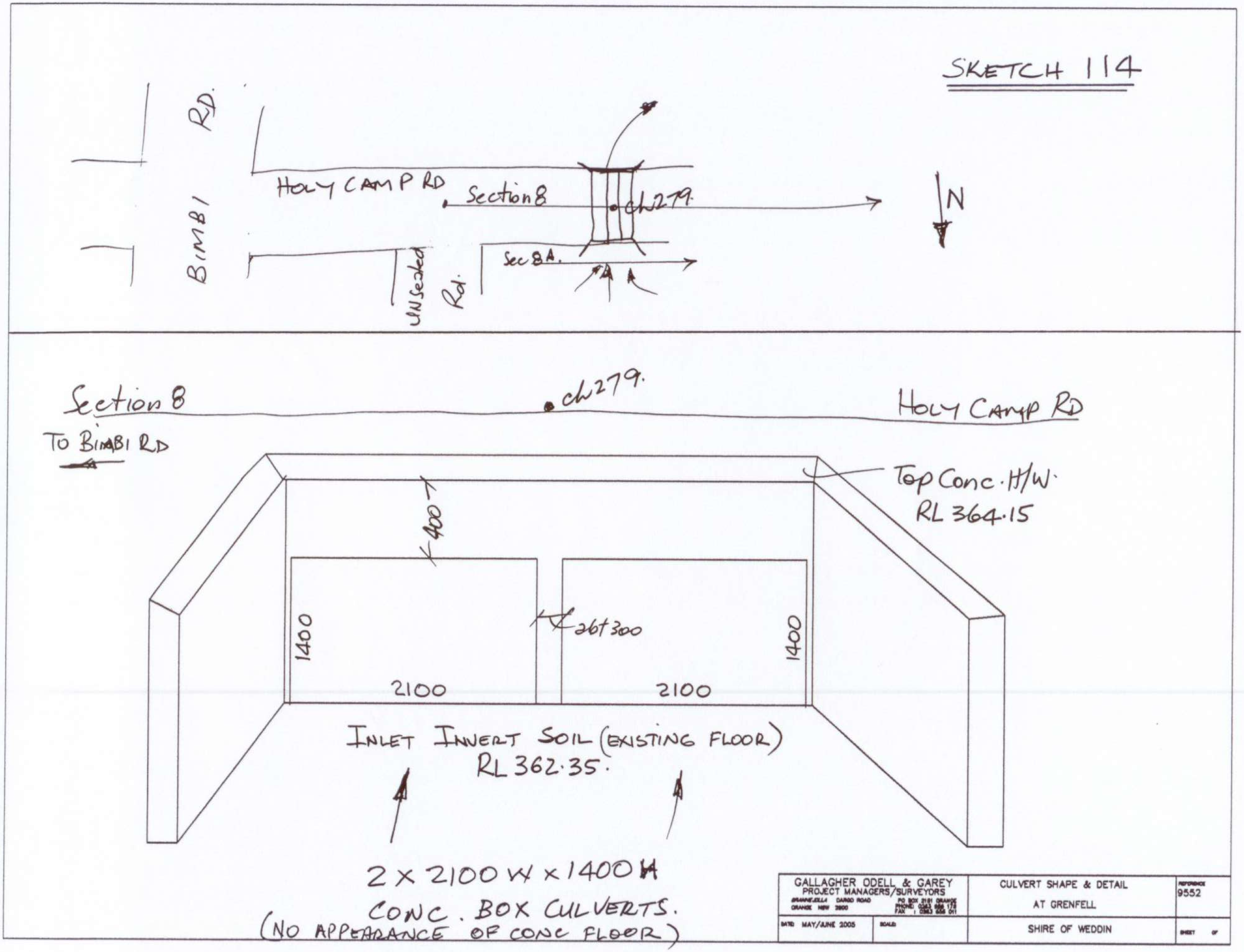
INLET INVERT RL 366·14.

1 375mm Φ RCP
(STANDARD PRECAST H/W·).

GALLAGHER ODELL & GAREY PROJECT MANAGERS/SURVEYORS	CULVERT SHAPE & DETAIL AT GRENFELL	REFERENCE 9552
DATE: MAY/JUNE 2005 SCALE:	SHIRE OF WEDDIN	SHEET OF

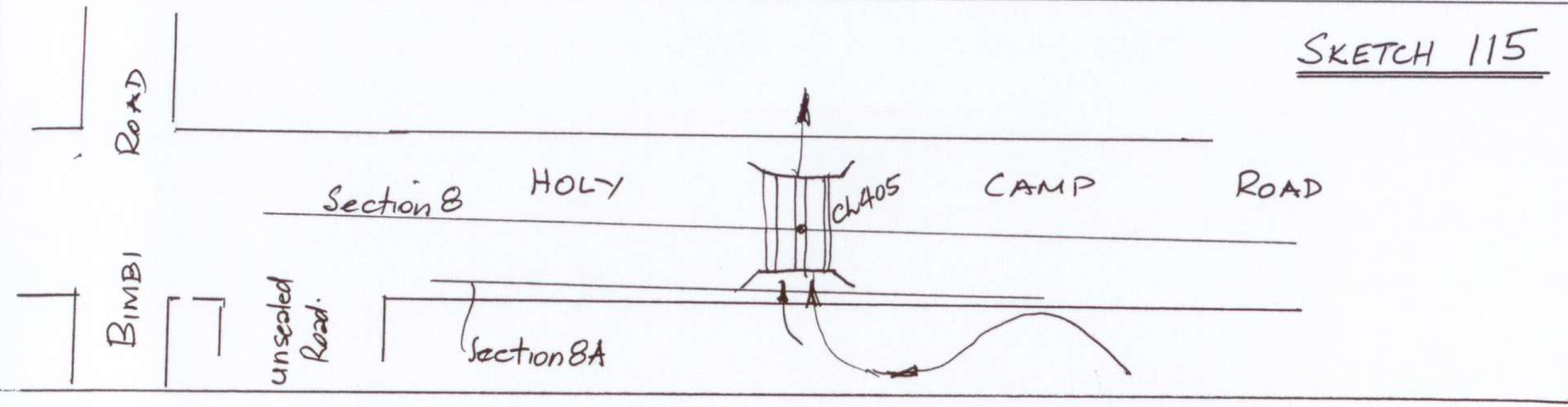


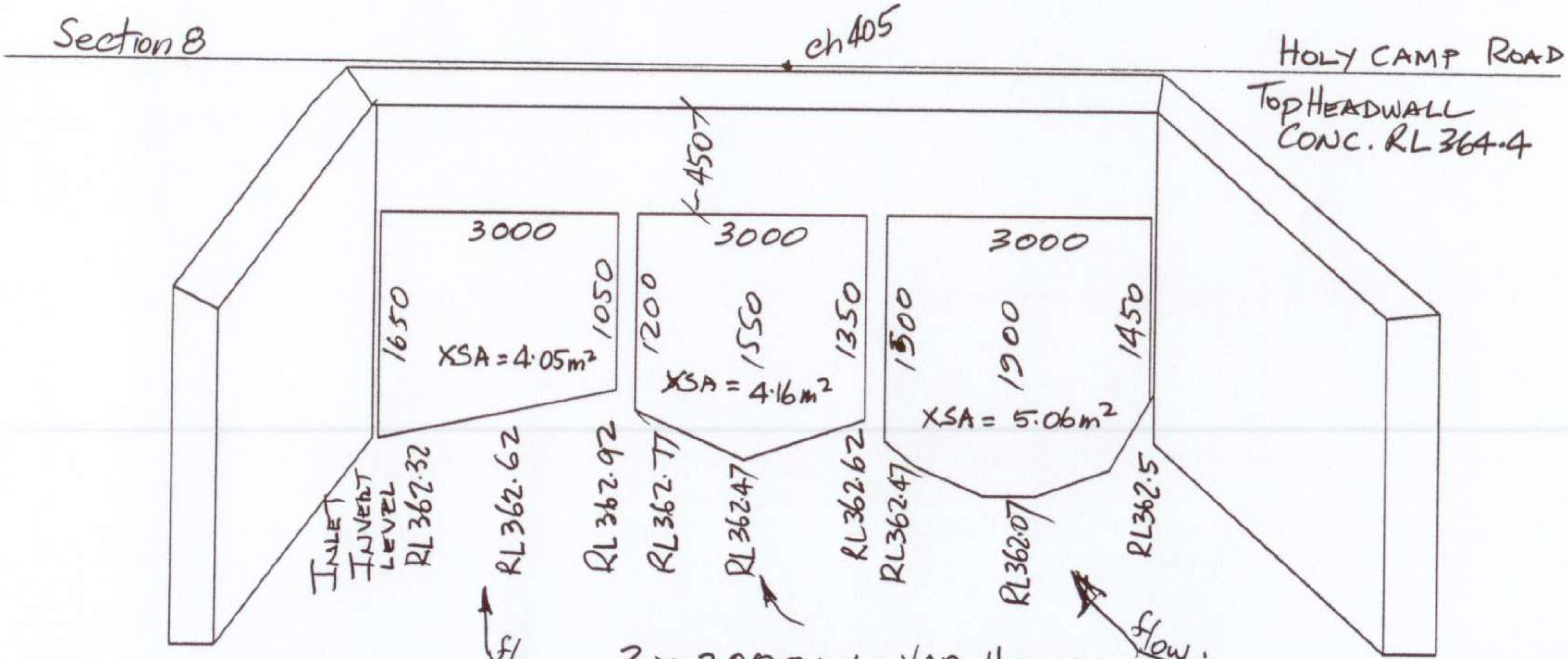
GALLAGHER ODELL & GAREY PROJECT MANAGERS/SURVEYORS	CULVERT SHAPE & DETAIL AT GRENFELL	REFERENCE 9552
DATED MAY/JUNE 2005 SCALE	SHIRE OF WEDDIN	SHEET OF



GALLAGHER ODELL & GAREY PROJECT MANAGERS/SURVEYORS	CULVERT SHAPE & DETAIL AT GRENFELL	REFERENCE 9552
DATE MAY/JUNE 2005 / SCALE	SHIRE OF WEDDIN	SHEET OF

SKETCH 115





3 × 3000 W × VAR. HEIGHT CONC. BOX CULVERTS.

(No apparent Conc. Floor)

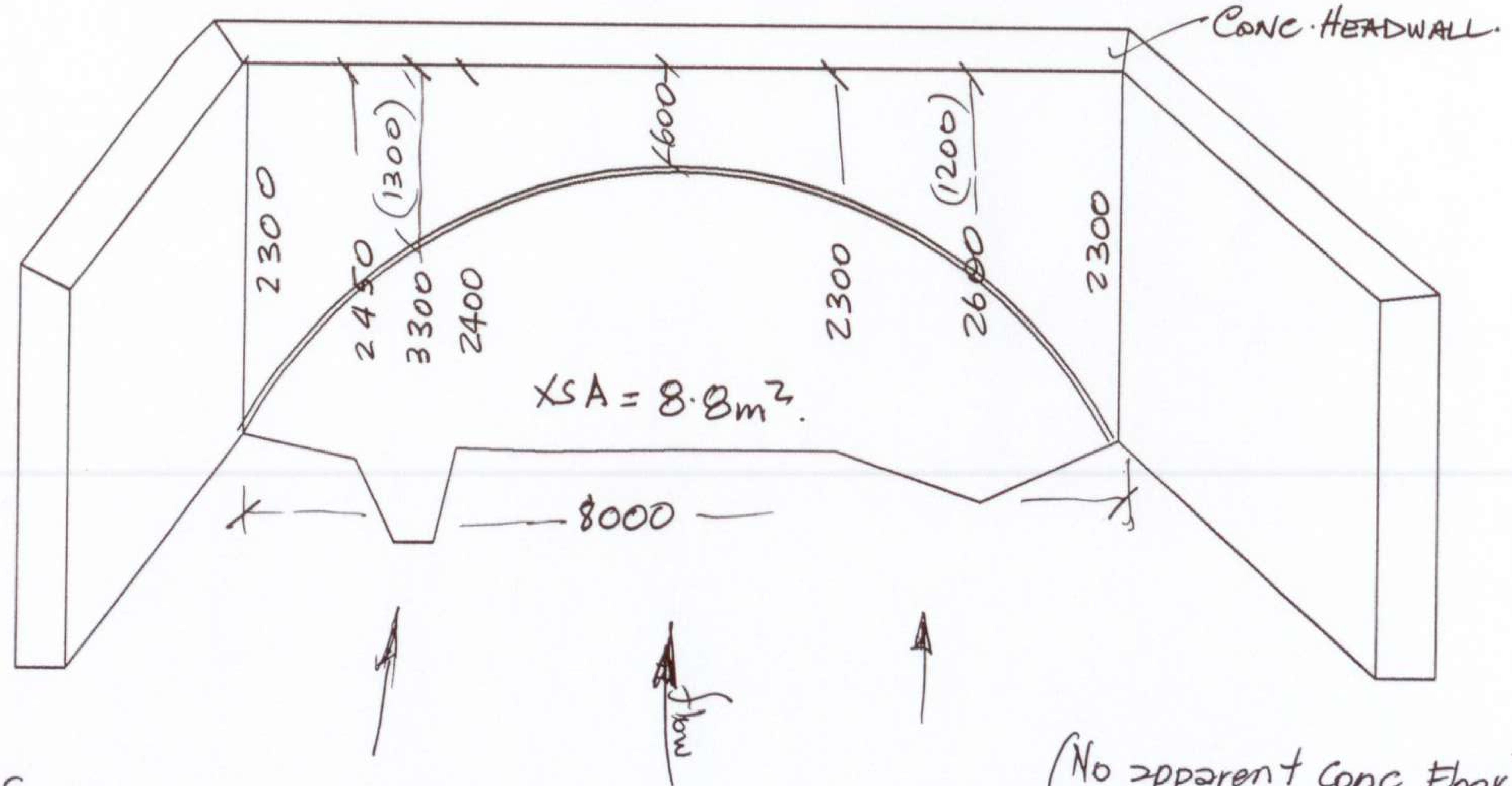
XSA = CROSS SECTIONAL AREA.

GALLAGHER ODELL & GAREY PROJECT MANAGERS/SURVEYORS	CULVERT SHAPE & DETAIL AT GRENFELL	REFERENCE 9552
DATE: MAY/JUNE 2005	SCALE:	SHIRE OF WEDDIN	SHEET OF

SKETCH 116

EUALDRIE ROAD.

RD LEVEL + 200 mm above H/W.



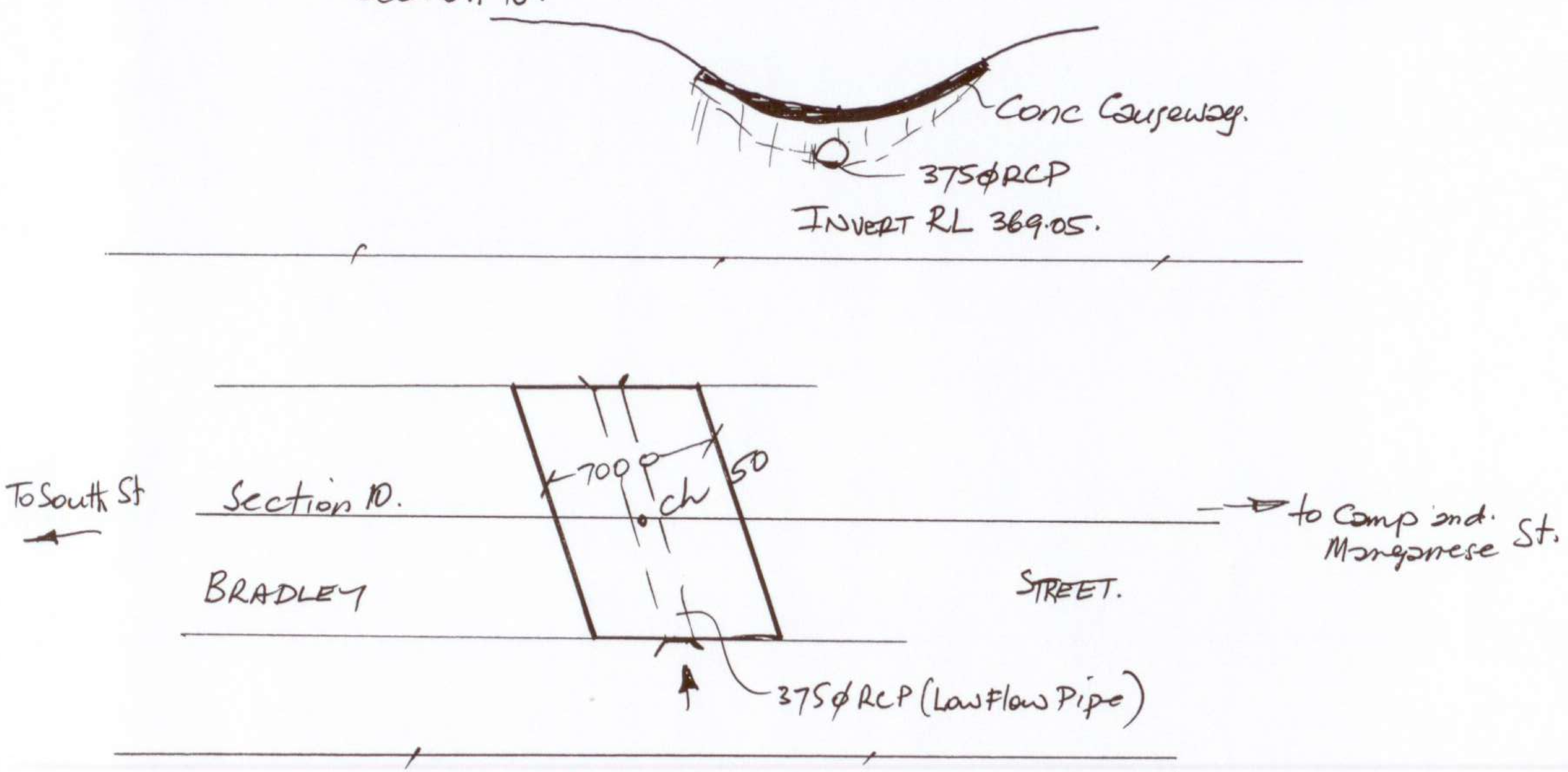
(No apparent Conc. Floor)

XSA = CROSS SECTIONAL AREA.

8000 W × VARIABLE HEIGHT
SEMI ELLIPSE CONC. CULVERT.

GALLAGHER ODELL & GAREY PROJECT MANAGERS/SURVEYORS	CULVERT SHAPE& DETAIL AT GRENFELL	REFERENCE 9552
DATE MAY/JUNE 2006 SCALE	SHIRE OF WEDDIN	SHEET OF

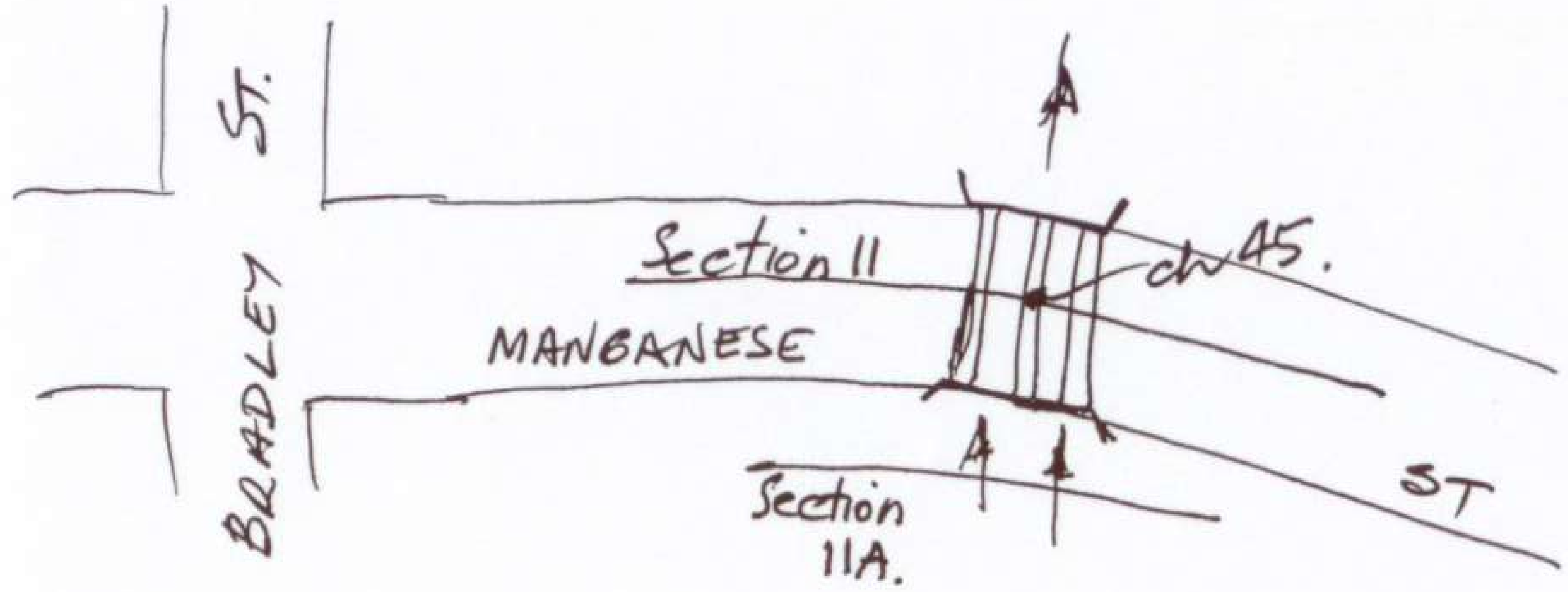
SKETCH 117

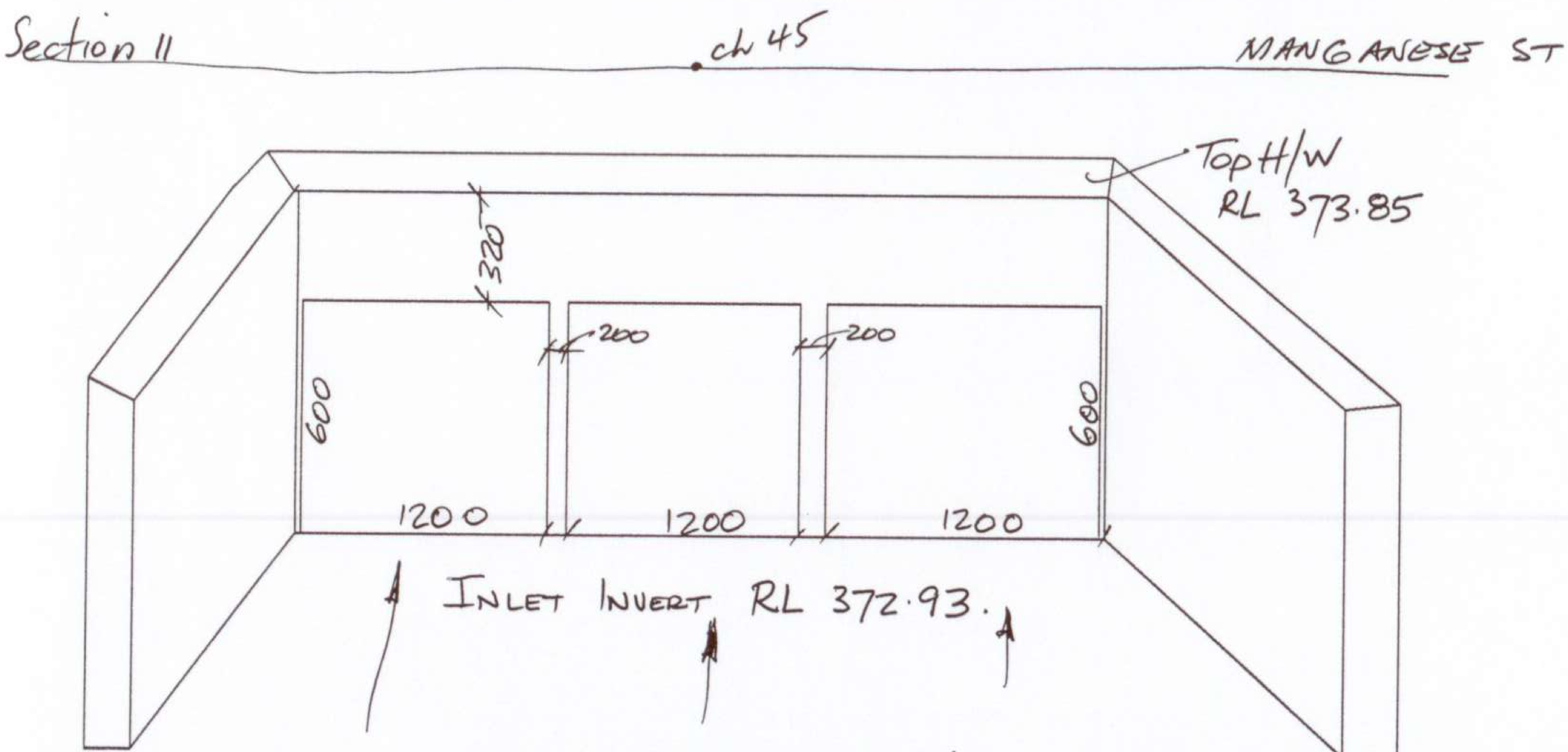


CONC. CAUSEWAY 7 WIDE
(375Ø RCP Low Flow Pipe)

GALLAGHER ODELL & GAREY PROJECT MANAGERS/SURVEYORS		CULVERT SHAPE & DETAIL AT GRENFELL	REFERENCE 9552
DATED MAY/JUNE 2005	SCALED	SHIRE OF WEDDIN	SHEET OF

SKETCH 118

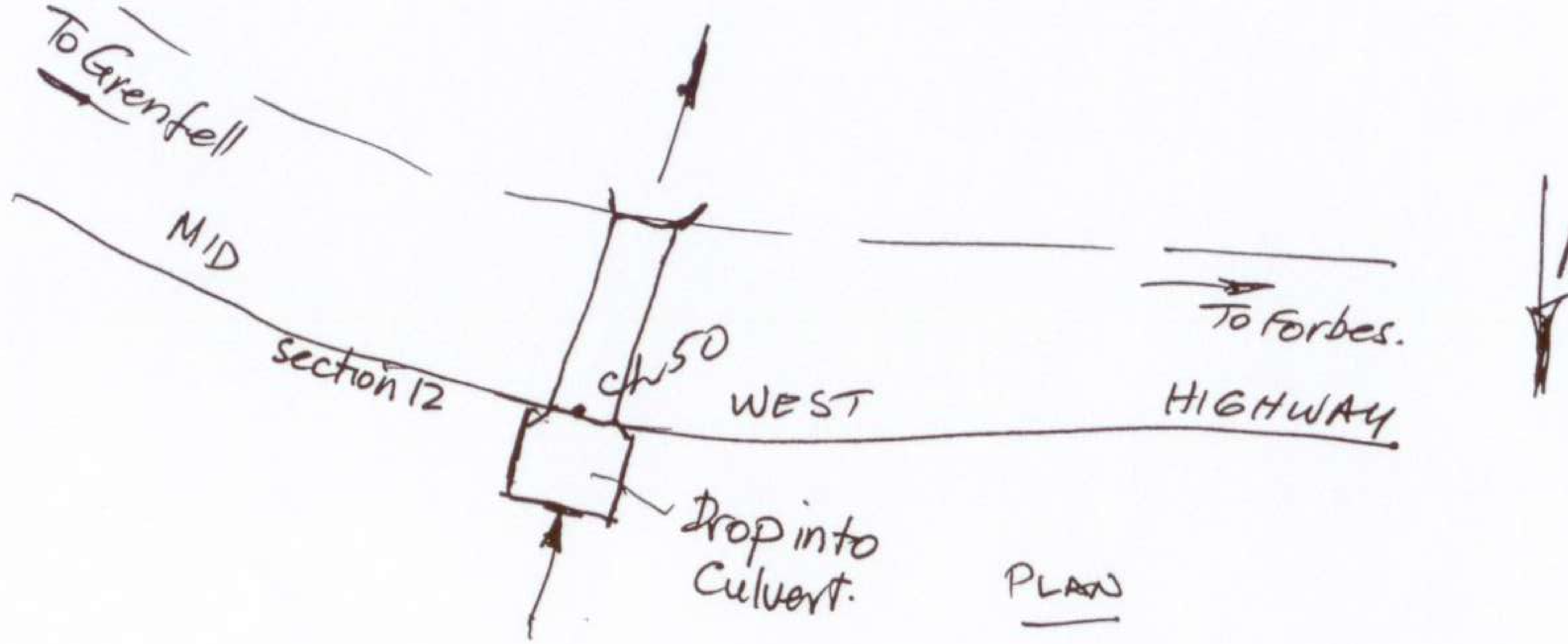




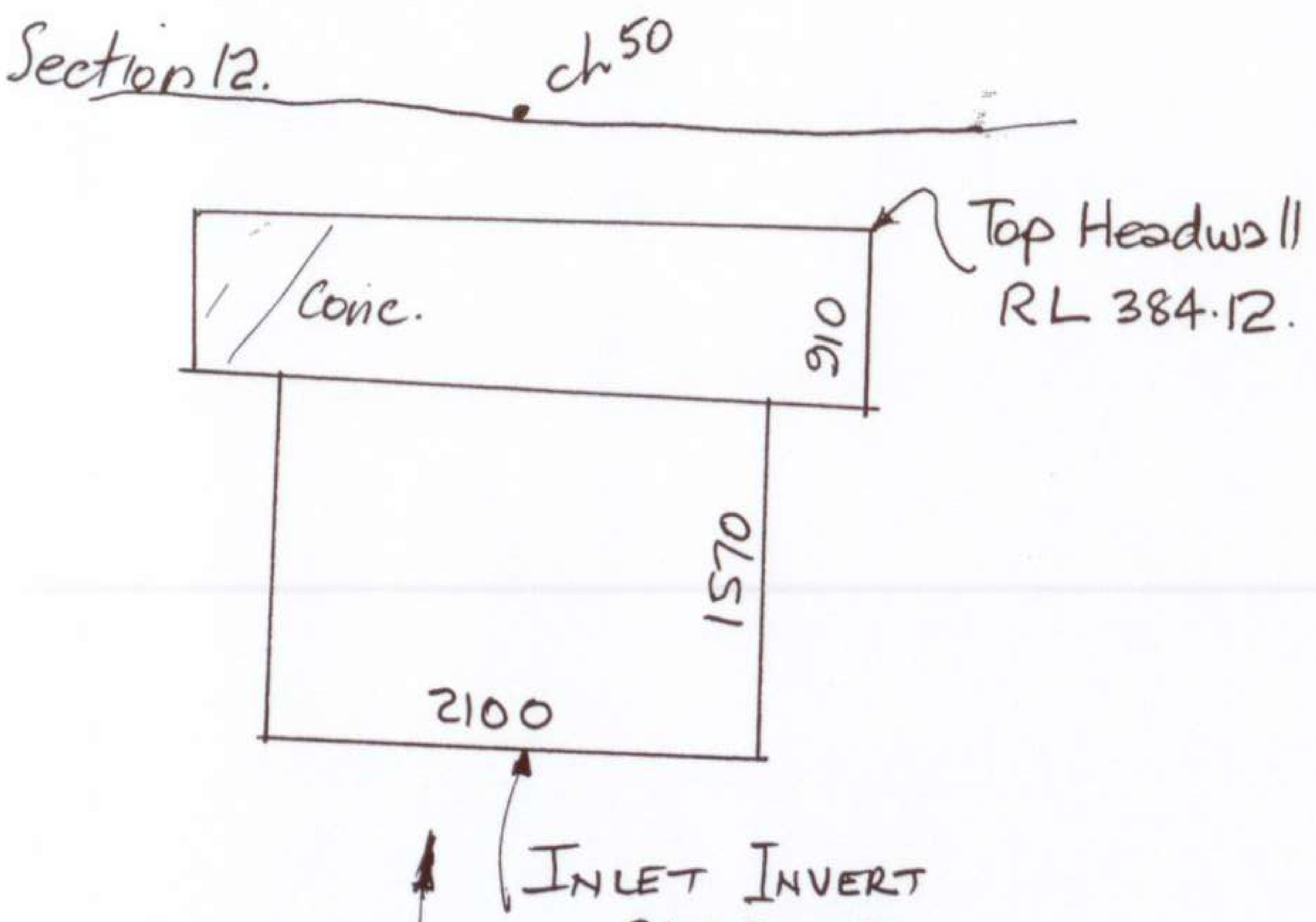
3 x 1200W x 600H
CONC. BOX CULVERTS

GALLAGHER ODELL & GAREY PROJECT MANAGERS/SURVEYORS	CULVERT SHAPE & DETAIL AT GRENFELL	REFERENCE 9552
DATE: MAY/JUNE 2005 / SCALE:	SHIRE OF WEDDIN	SHEET OF

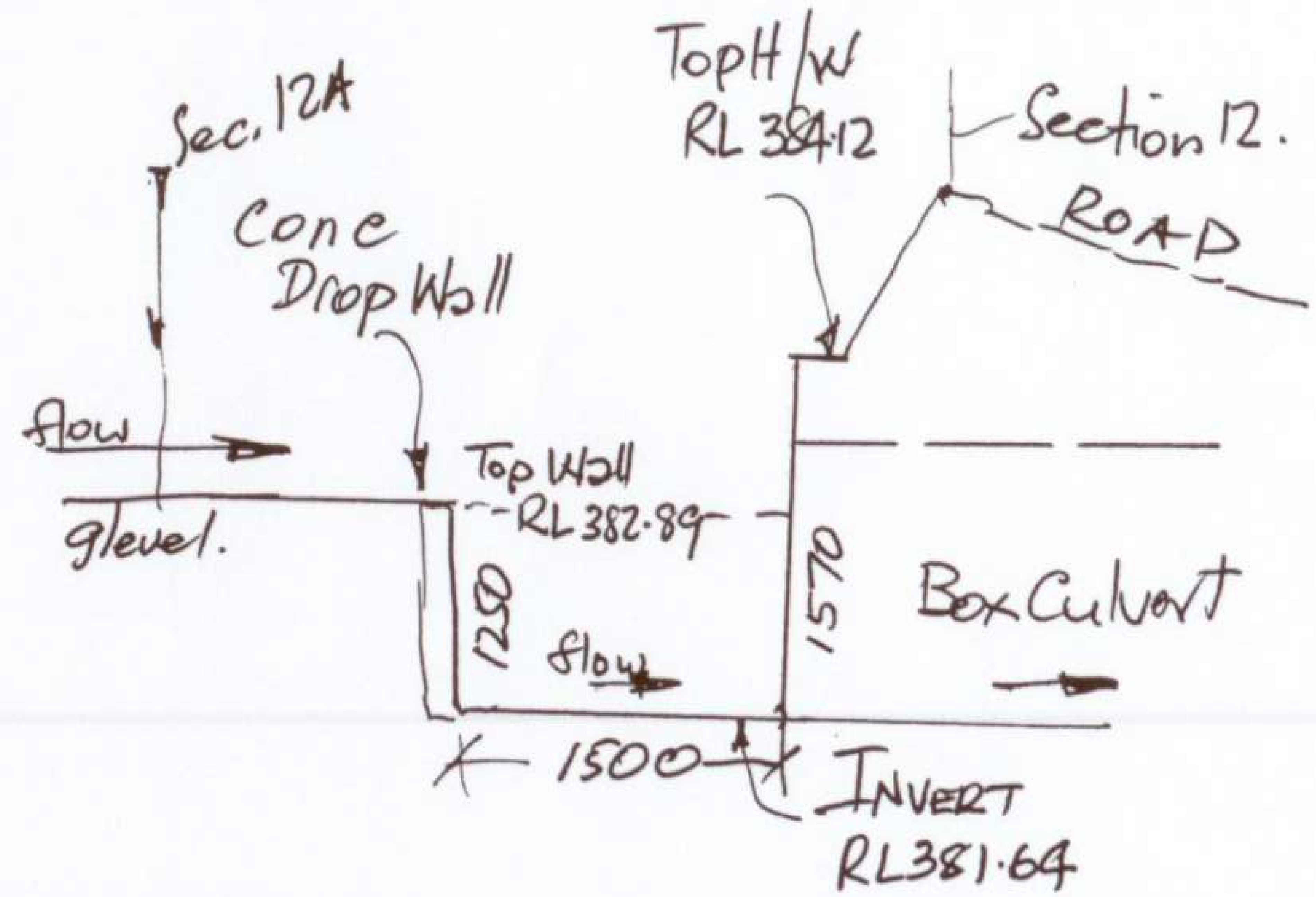
SKETCH 119



PLAN

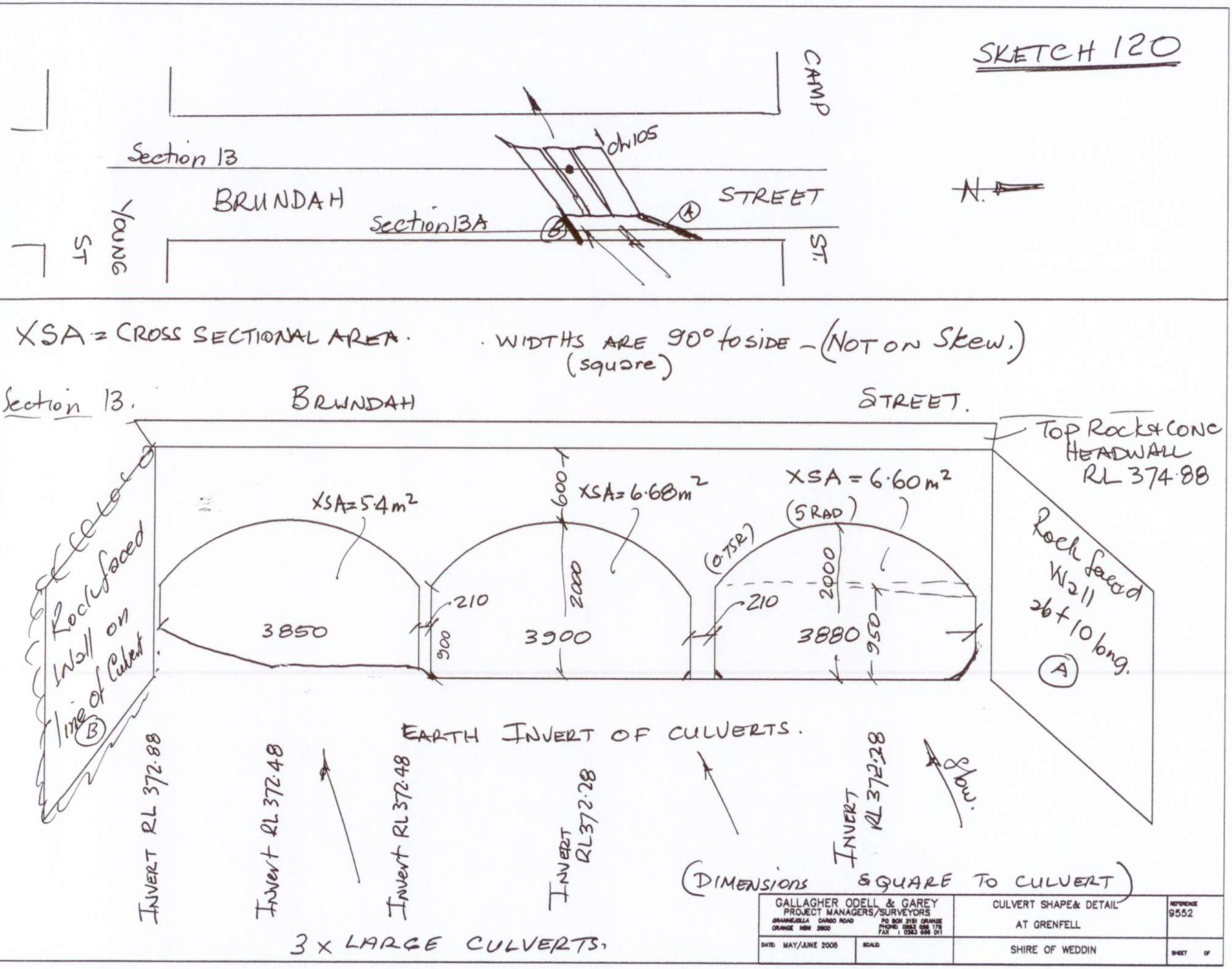


SINGLE 2100W × 1570H
CONC. BOX CULVERT.

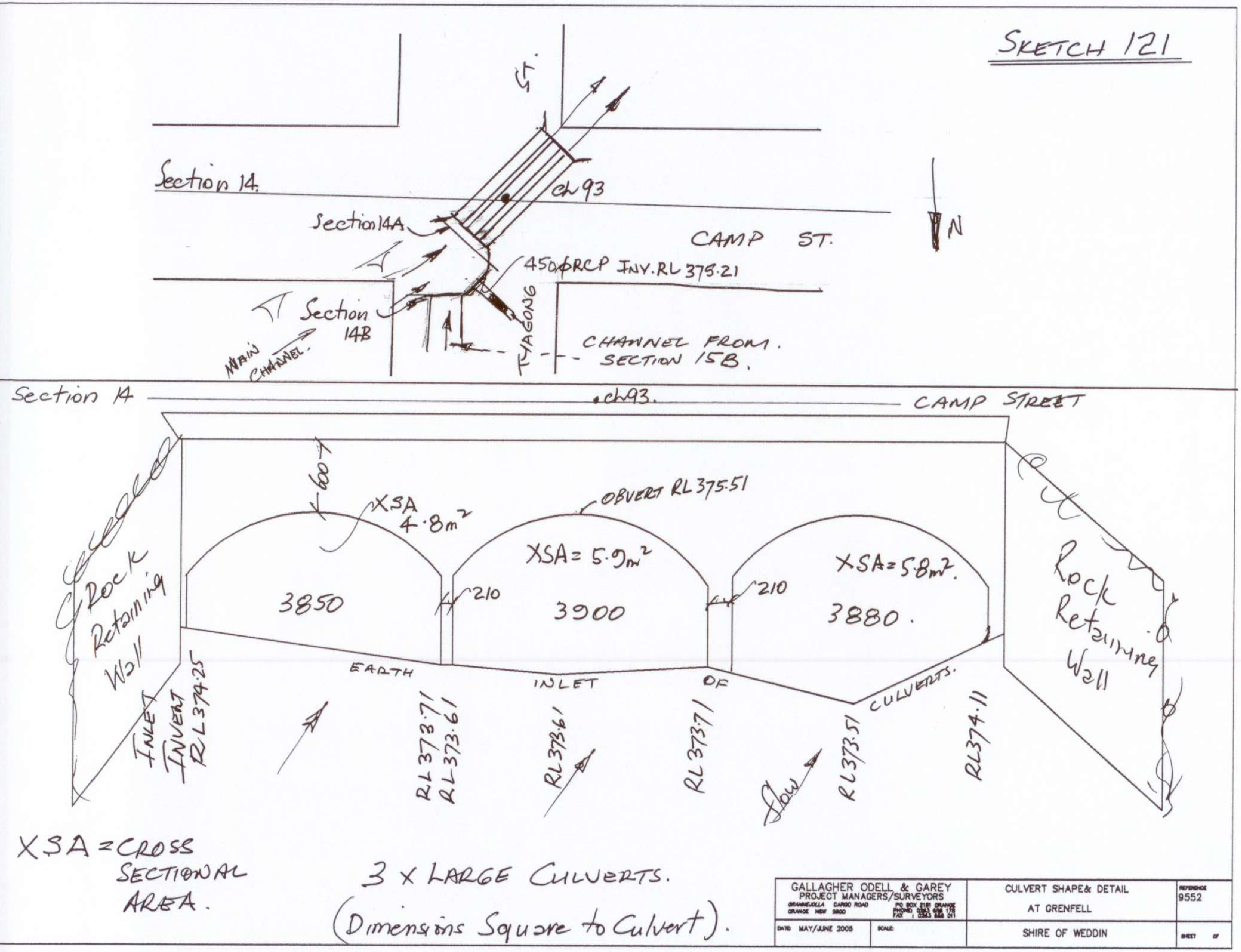


SIDE ELEVATION OF DROP PIT INTO CULVERT.

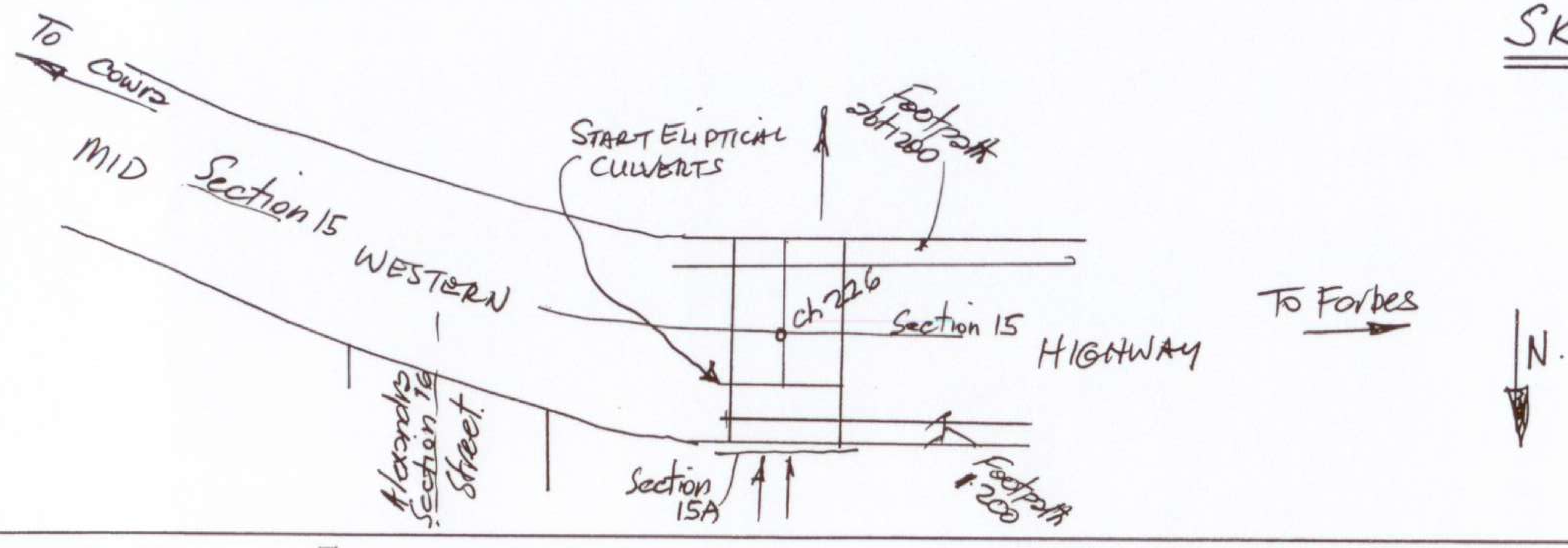
GALLAGHER ODELL & GAREY PROJECT MANAGERS/SURVEYORS		CULVERT SHAPE & DETAIL AT GRENFELL	REFERENCE 9552
DATE MAY/JUNE 2005	SCALE	SHIRE OF WEDDIN	SHEET OF

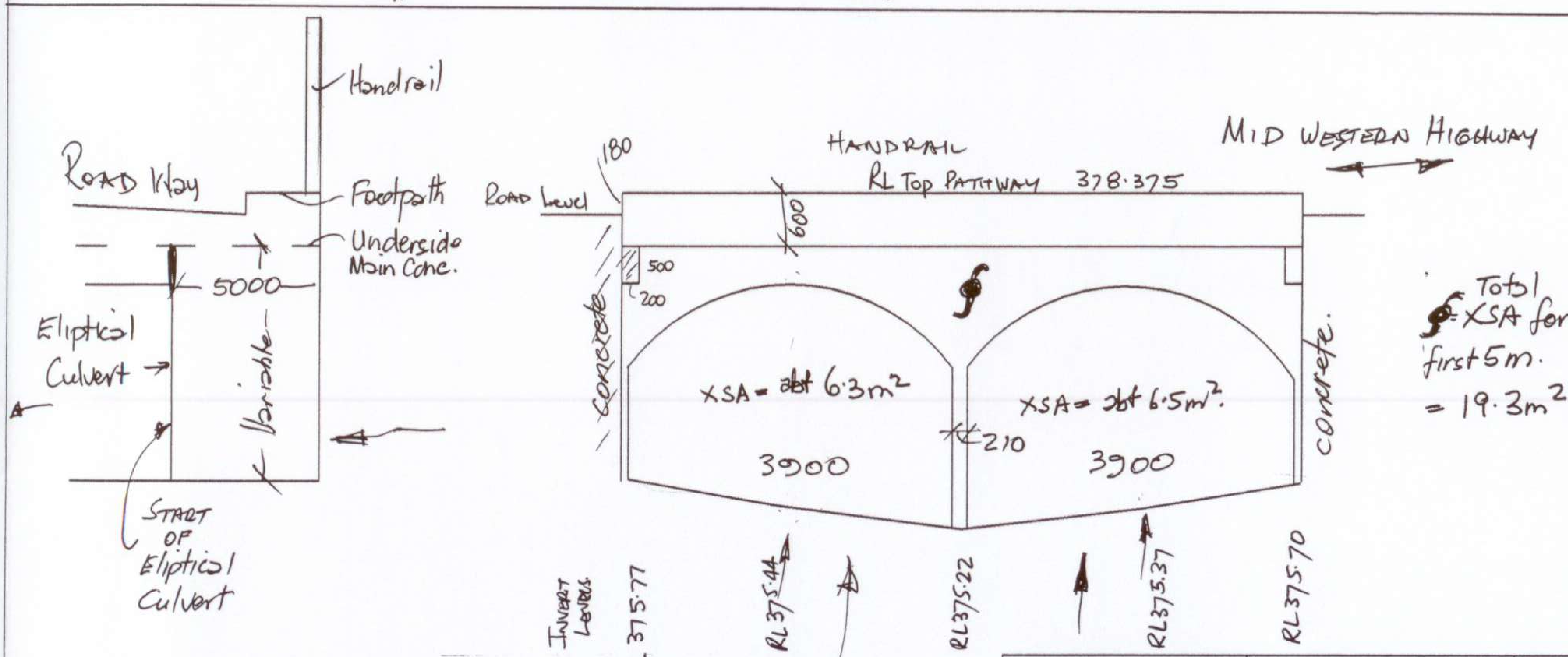


SKETCH 120
CAMP
STREET
ST.
Section 13
BRUNDAH
Section 13A
YOUNG
ST
ch105
A
B
N.
XSA = CROSS SECTIONAL AREA.
WIDTHS ARE 90° to SIDE – (NOT ON Skew.)
(square)
Section 13.
BRUNDAH
STREET.
Top Rock & Conc
HEADWALL
RL 374·88
XSA = 5·4m²
XSA = 6·68m²
XSA = 6·60m²
(5 RAD)
(0.75R)
600
2000
2000
210
210
900
950
3850
3900
3880
Rock faced
Wall
26 + 10 long.
A
Rockfaced
Wall on
line of Culvert
B
EARTH INVERT OF CULVERTS.
Flow.
INVERT RL 372·88
Invert RL 372·48
Invert RL 372·48
INVERT RL 372·28
INVERT RL 372·28
(DIMENSIONS SQUARE TO CULVERT)
3 x LARGE CULVERTS.
GALLAGHER ODELL & GAREY
PROJECT MANAGERS/SURVEYORS
CULVERT SHAPE & DETAIL
AT GRENFELL
SHIRE OF WEDDIN
REFERENCE
9552
DATE: MAY/JUNE 2005
SCALE
SHEET OF


SKETCH 121
Section 14.
ch93
Section 14A
CAMP ST.
N
450φRCP INV. RL 375.21
Section 14B
MAIN CHANNEL.
JIAGONG
CHANNEL FROM. SECTION 15B.
Section 14
ch93.
CAMP STREET
600
XSA 4.8m²
OBVERT RL 375.51
XSA = 5.9m²
XSA = 5.8m².
Rock Retaining Wall
3850
210
3900
210
3880.
Rock Retaining Wall
EARTH
INLET
OF
CULVERTS.
INLET INVERT RL 374.25
RL 373.71
RL 373.61
RL 373.61
RL 373.71
Flow
RL 373.51
RL 374.11
XSA = CROSS SECTIONAL AREA.
3 x LARGE CULVERTS.
(Dimensions Square to Culvert).
GALLAGHER ODELL & GAREY
PROJECT MANAGERS/SURVEYORS
DATE MAY/JUNE 2005
SCALE
CULVERT SHAPE& DETAIL
AT GRENFELL
SHIRE OF WEDDIN
REFERENCE 9552
SHEET OF

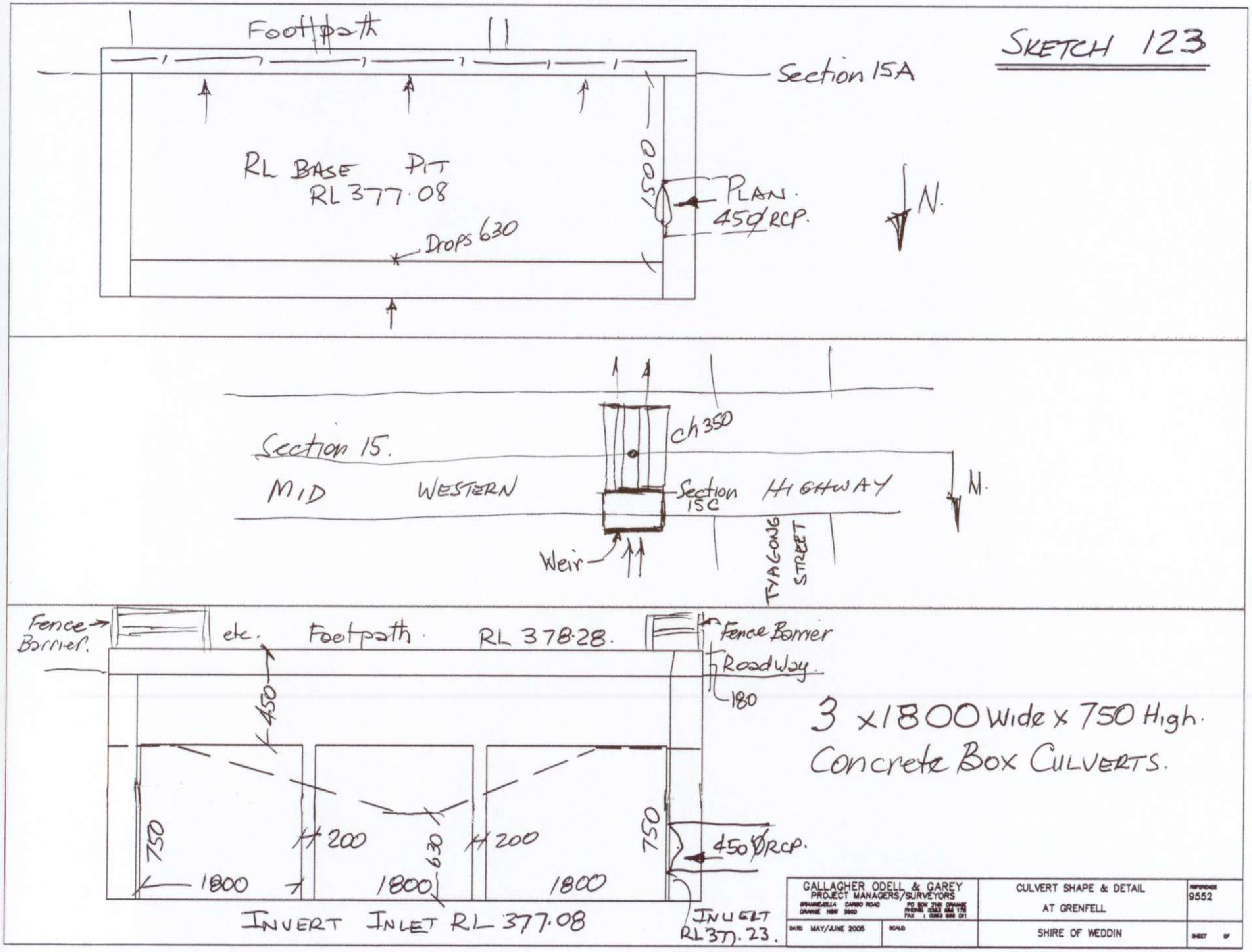
SKETCH 122





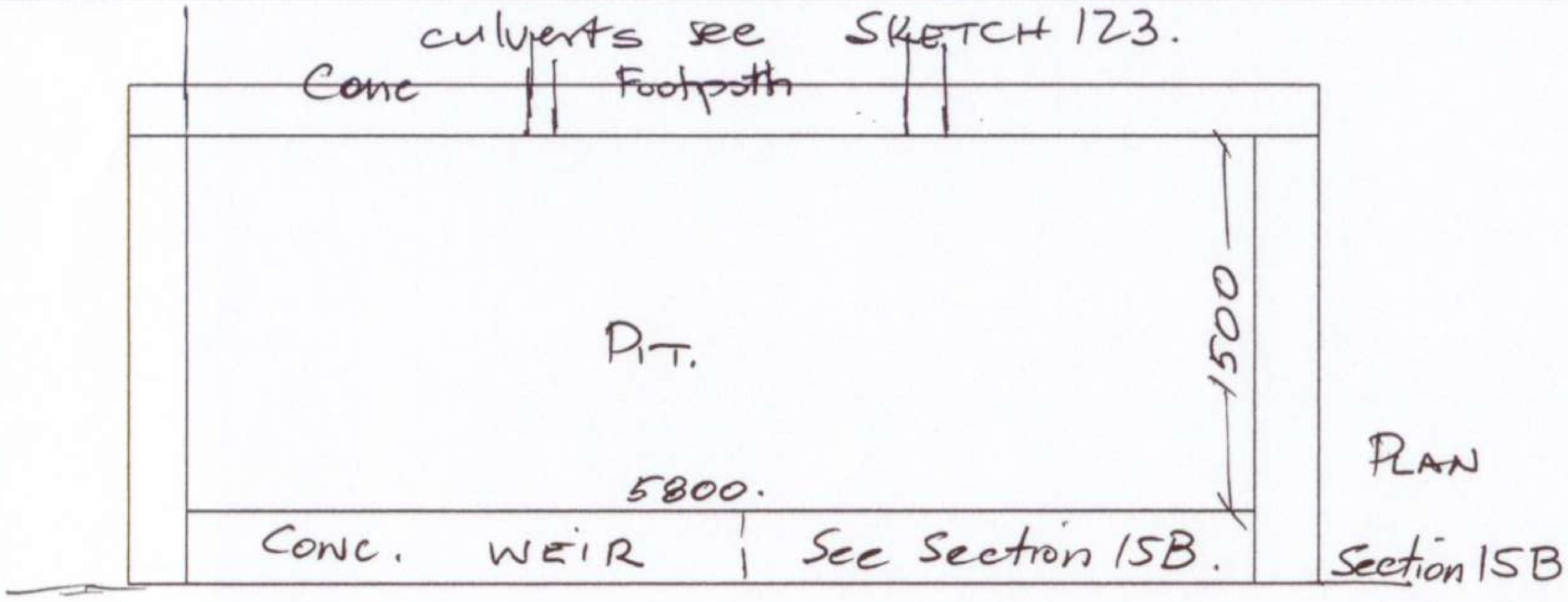
XSA = CROSS SECTIONAL AREA.

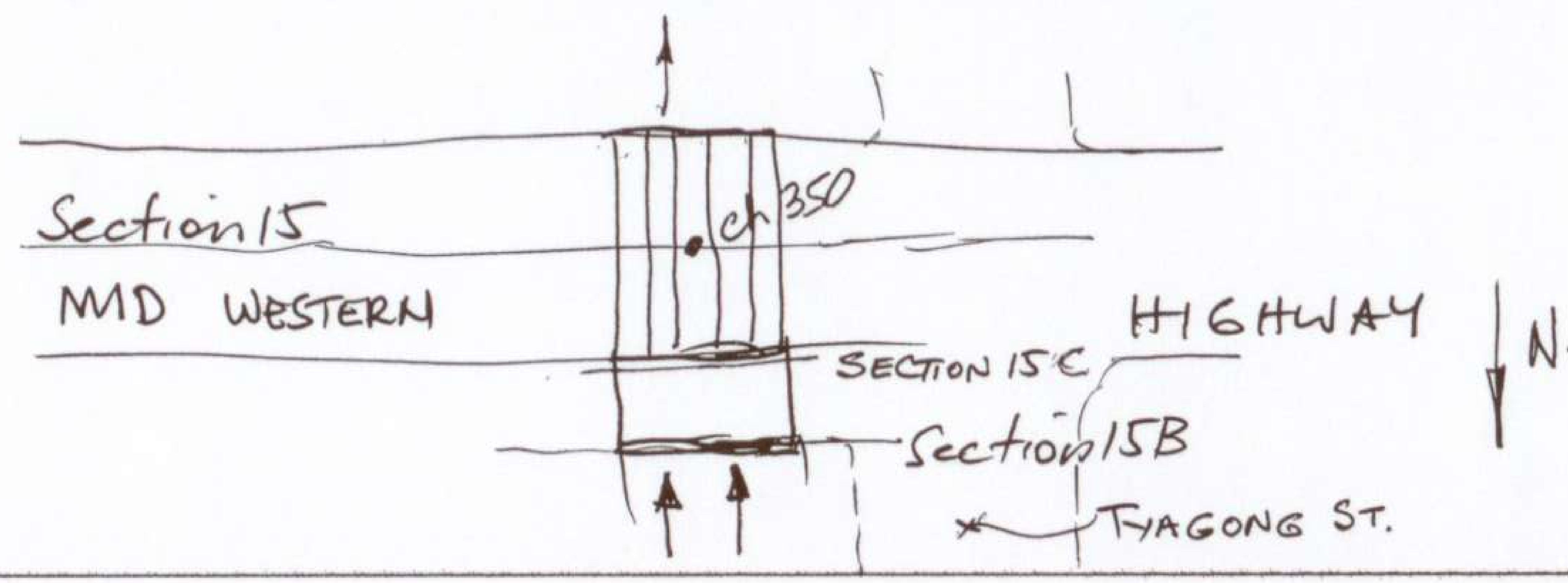
GALLAGHER ODELL & GAREY PROJECT MANAGERS/SURVEYORS	CULVERT SHAPE& DETAIL AT GRENFELL	REFERENCE 9552
DATE MAY/JUNE 2008	SHIRE OF WEDDIN	SHEET OF

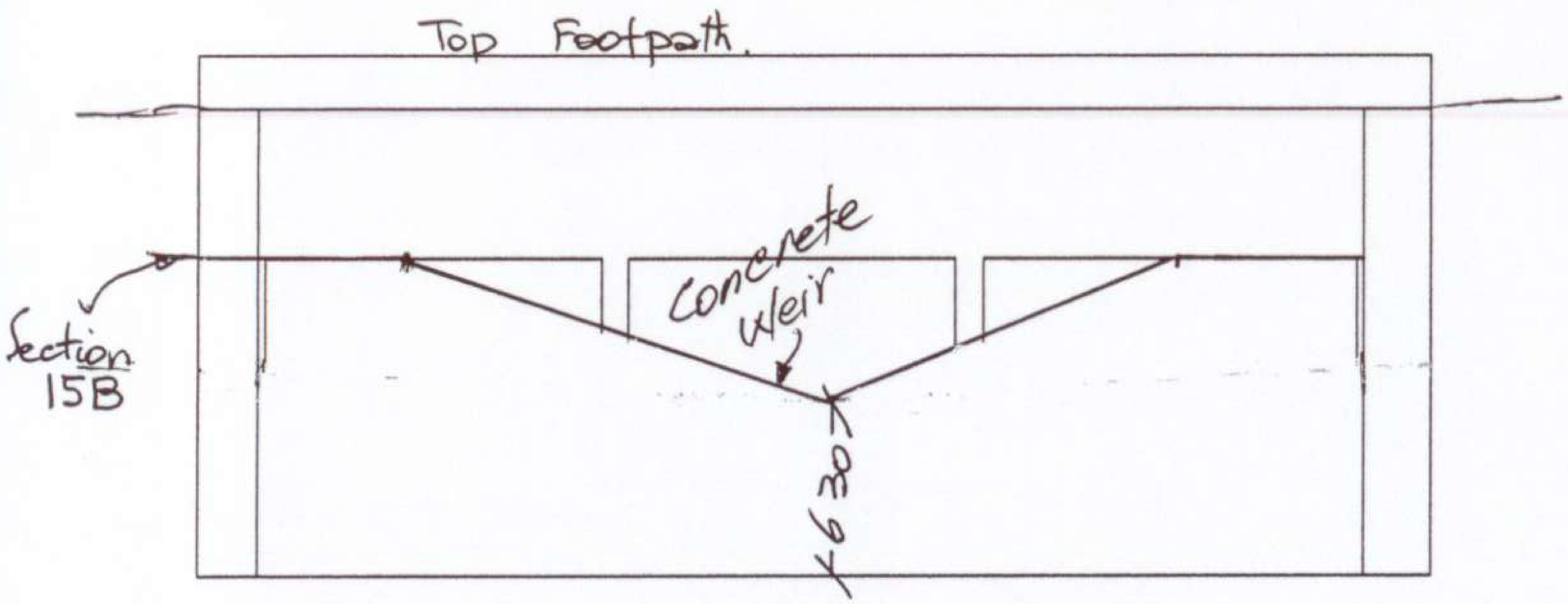


SKETCH 123
Footpath
Section 15A
RL BASE PIT
RL 377.08
Drops 630
1500
PLAN.
450Ø RCP.
N.
Section 15.
MID WESTERN HIGHWAY
ch 350
Section 15C
Weir
TYAGONG STREET
N.
Fence Barrier.
etc.
Footpath.
RL 378.28.
Fence Barrier
Roadway.
180
450
750
200
630
200
750
1800
1800
1800
450Ø RCP.
INVERT INLET RL 377.08
INLET RL 377.23.
3 x 1800 Wide x 750 High.
Concrete Box Culverts.
GALLAGHER ODELL & GAREY
PROJECT MANAGERS/SURVEYORS
CULVERT SHAPE & DETAIL
AT GRENFELL
SHIRE OF WEDDIN
9552
DATE MAY/JUNE 2005

SKETCH 124



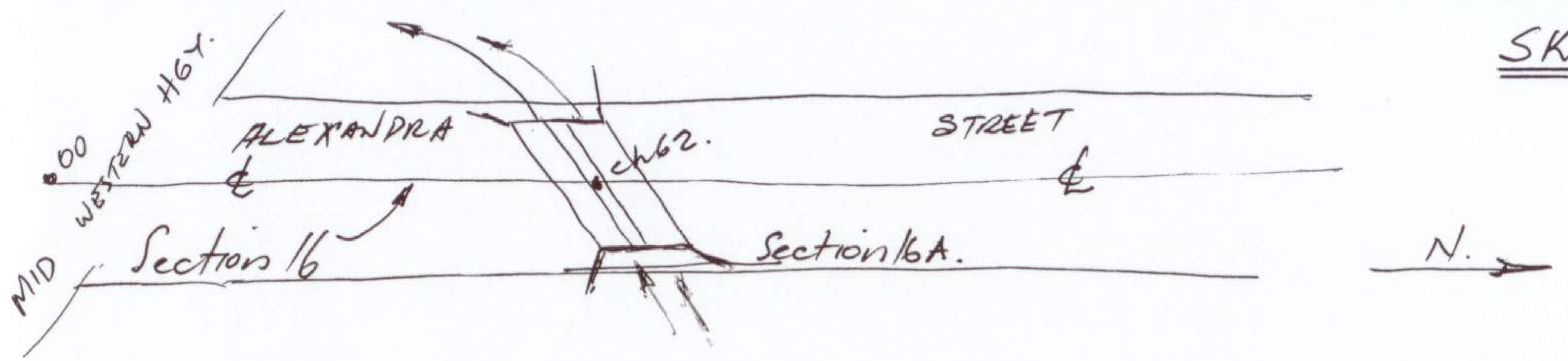


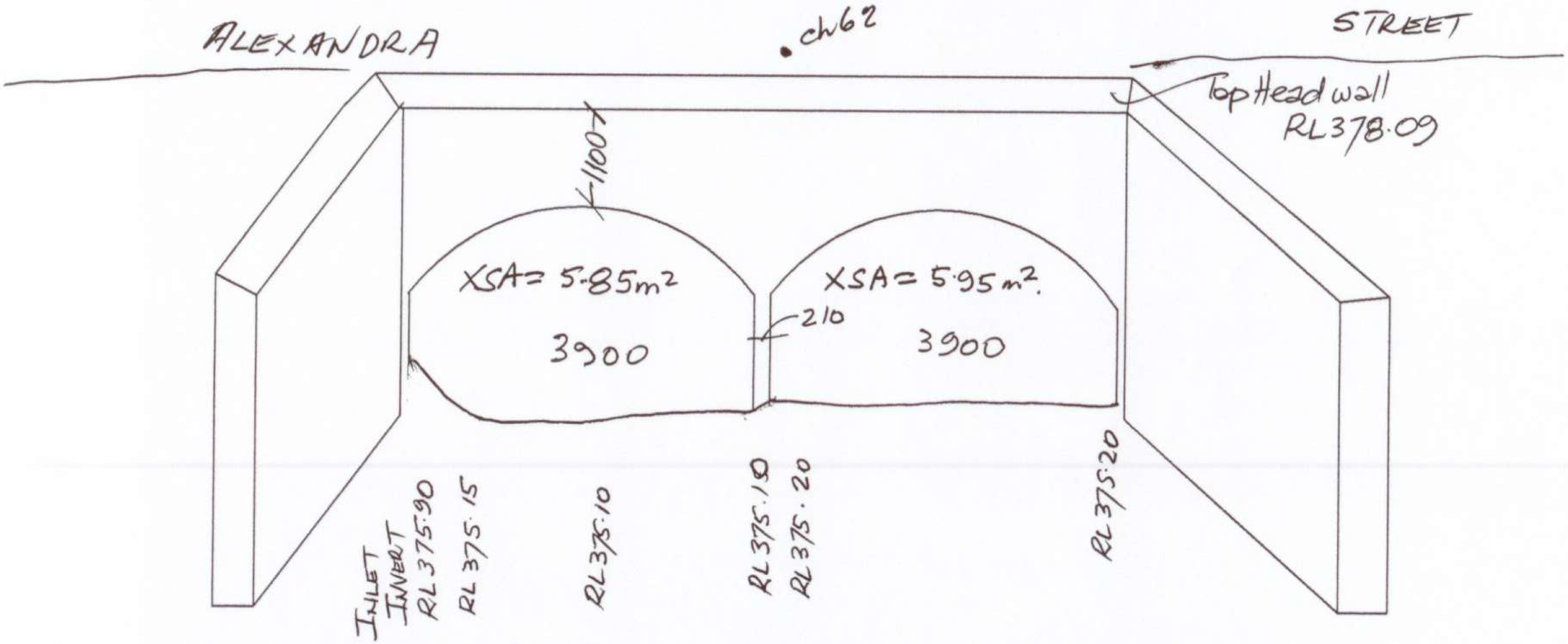


Weir
Drops into Pit before
entering culverts.

GALLAGHER ODELL & GAREY PROJECT MANAGERS/SURVEYORS GRANGE-JOLLA CARGO ROAD ORANGE NSW 2800 PO BOX 3131 ORANGE	CULVERT SHAPE & DETAIL AT GRENFELL	REFERENCE 9552
DATE MAY/JUNE 2005 SCALE	SHIRE OF WEDDIN	SHEET OF

SKETCH 125





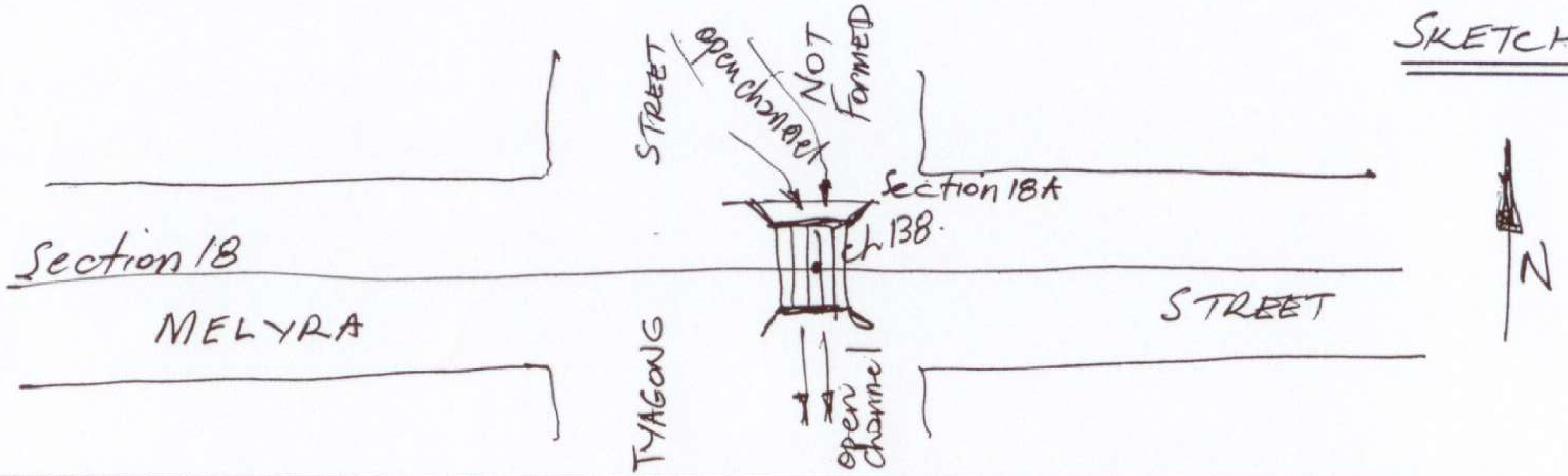
XSA = Cross Sectional Area.

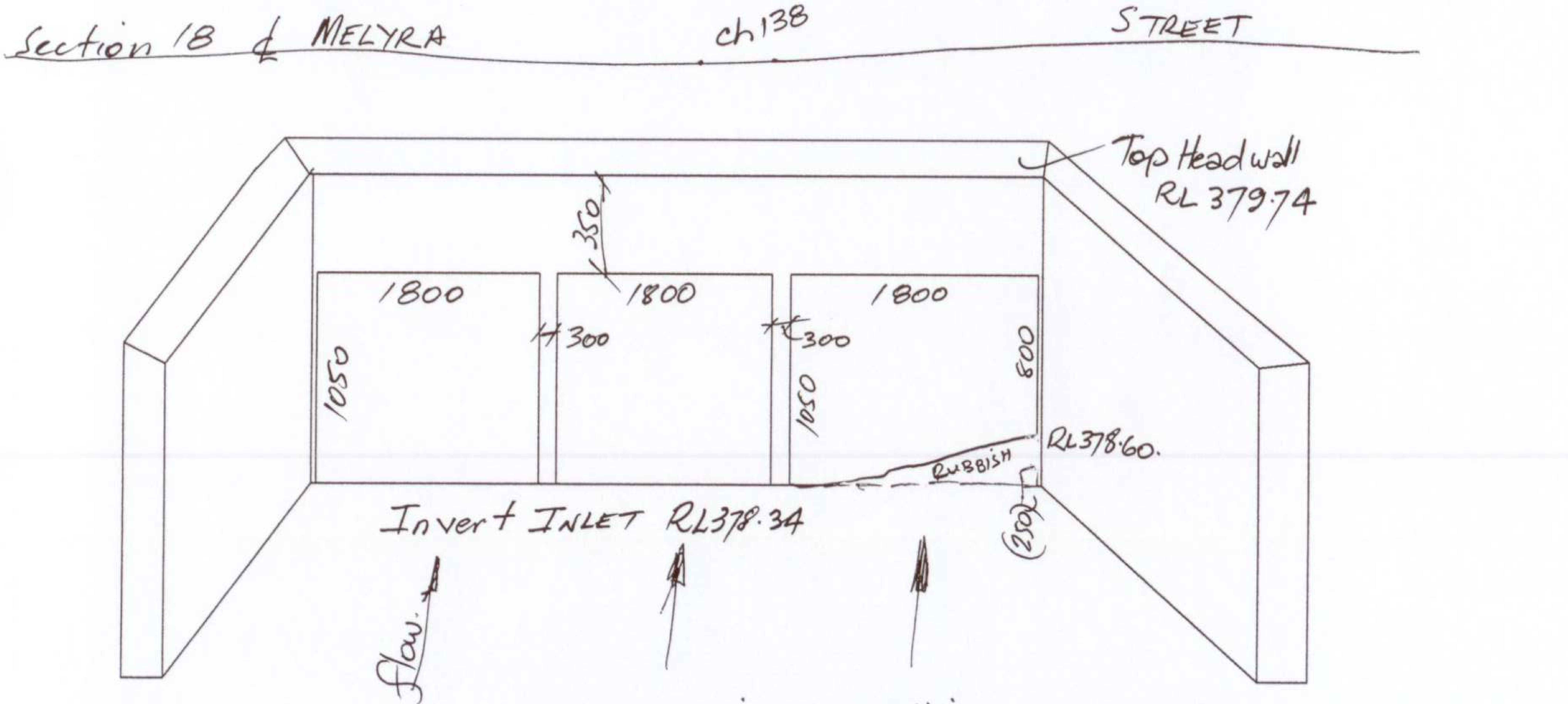
2 LARGE CULVERTS.

(Dimensions Square to Culvert Walls).

GALLAGHER ODELL & GAREY PROJECT MANAGERS/SURVEYORS GRANNEJOLLA CARGO ROAD ORANGE NSW 2800 PO BOX 2151 ORANGE PHONE: 0263 636 176 FAX: 0263 906 011	CULVERT SHAPE& DETAIL AT GRENFELL	REFERENCE 9552
DATE: MAY/JUNE 2005 SCALE:	SHIRE OF WEDDIN	SHEET OF

SKETCH 126

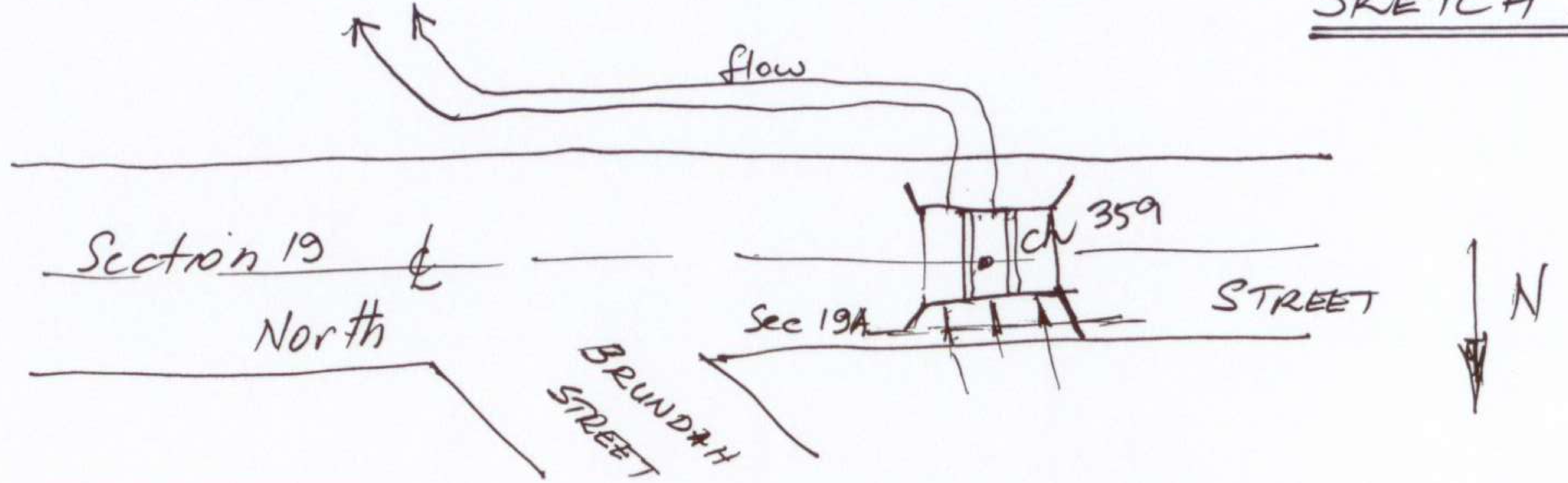


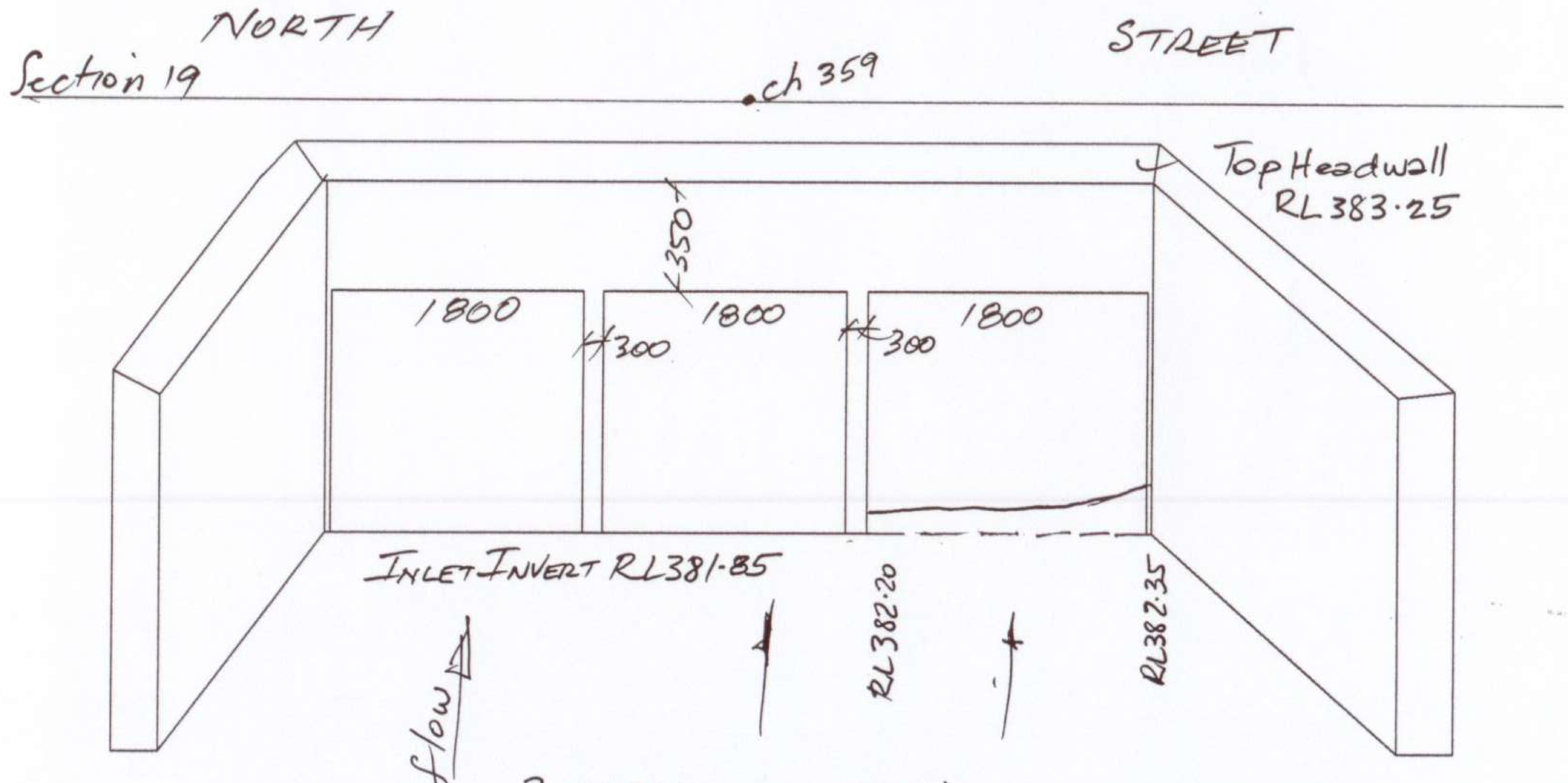


3 x 1800 Wide x 1050 High
Conc. Box Culverts

GALLAGHER ODELL & GAREY PROJECT MANAGERS/SURVEYORS GRANNEJOLLA CARGO ROAD ORANGE NSW 2800 PO BOX 3151 ORANGE PHONE: 02 63 656 175 FAX: 02 63 658 011	CULVERT SHAPE & DETAIL AT GRENFELL	REFERENCE 9552
DATE: MAY/JUNE 2005 SCALE:	SHIRE OF WEDDIN	SHEET OF

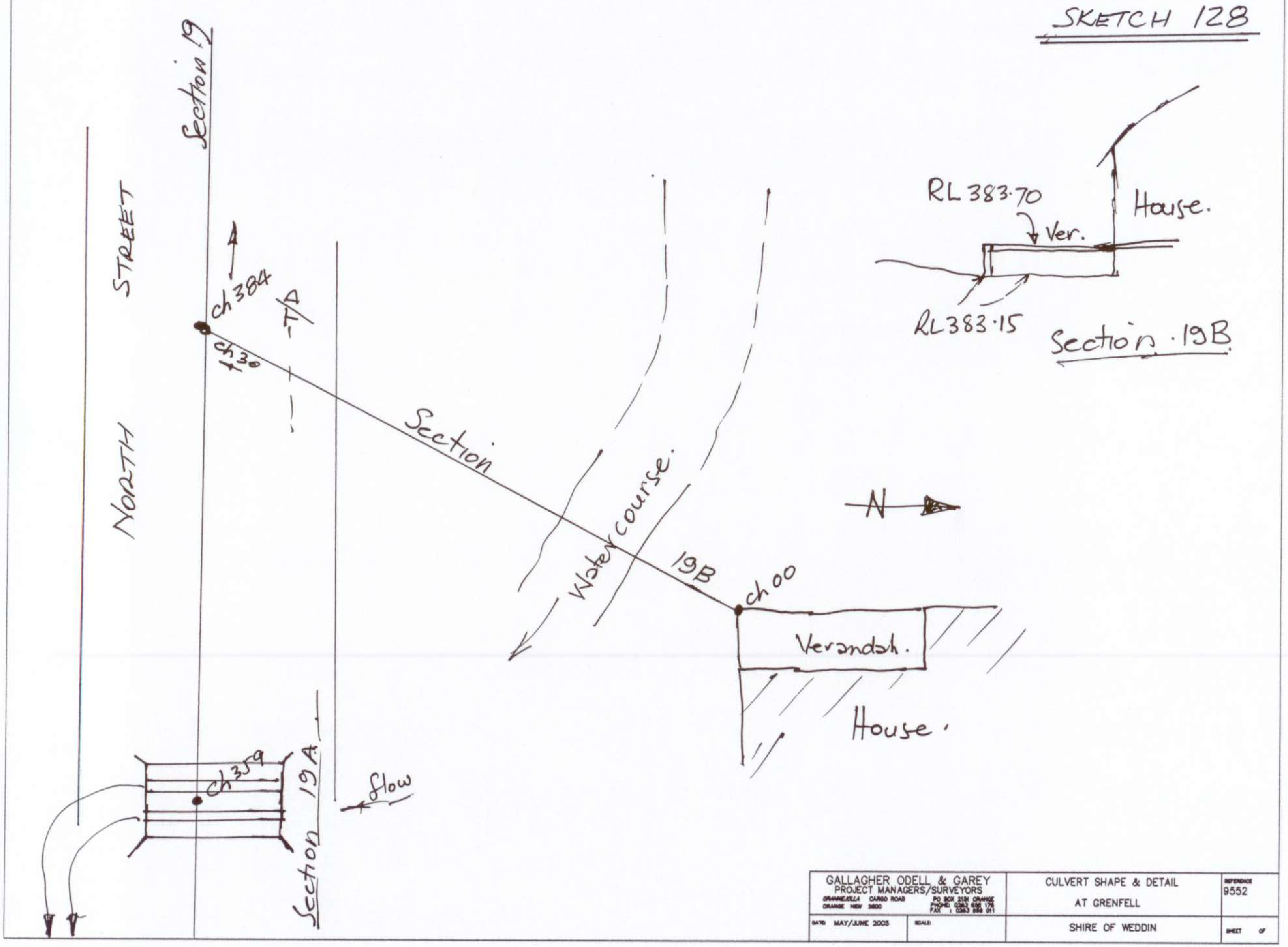
SKETCH 127



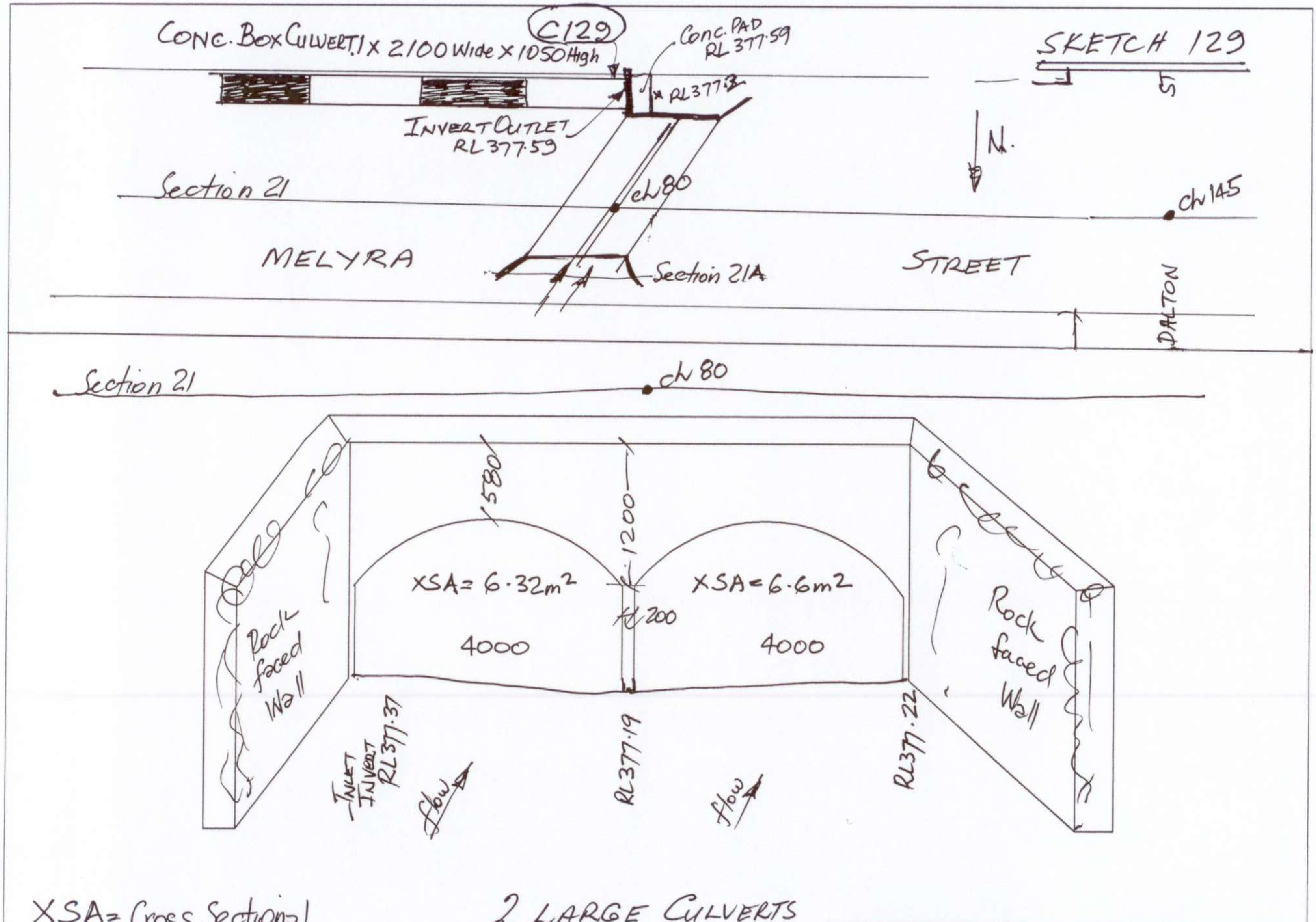


3 X 1800 wide x 1050 High
Conc. Box Culverts.

GALLAGHER ODELL & GAREY PROJECT MANAGERS/SURVEYORS	CULVERT SHAPE & DETAIL AT GRENFELL	REFERENCE 9552
DATE: MAY/JUNE 2005 SCALE:	SHIRE OF WEDDIN	SHEET OF

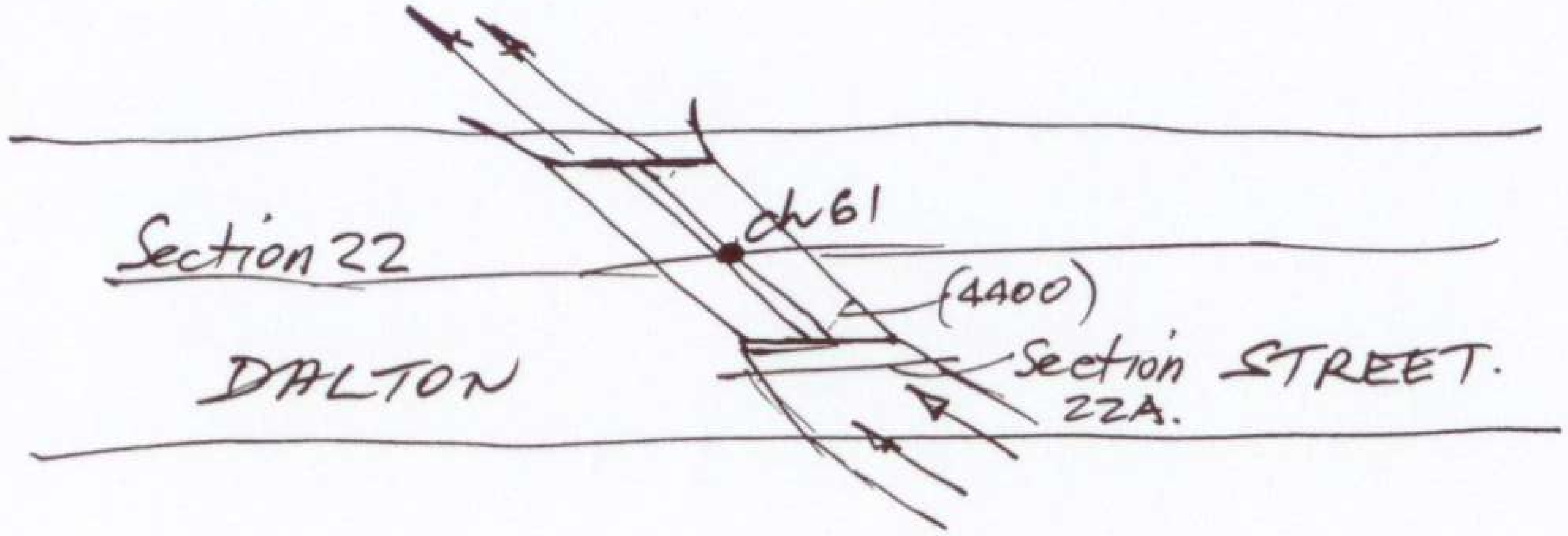


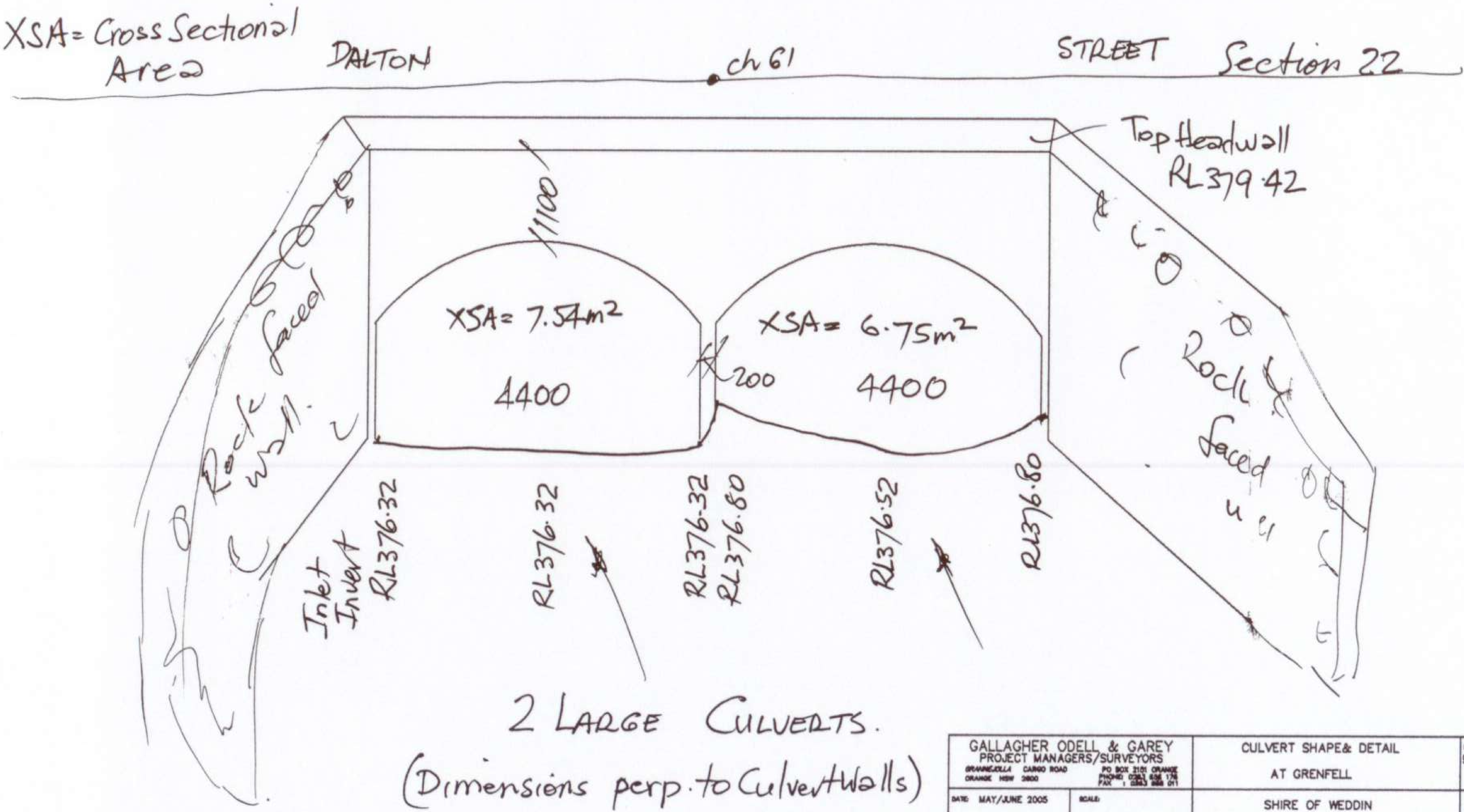
GALLAGHER ODELL & GAREY PROJECT MANAGERS/SURVEYORS GRANNIEJOLLA CARGO ROAD ORANGE NSW 2800 PO BOX 2151 ORANGE PHONE 02 63 636 178 FAX 02 63 898 011	CULVERT SHAPE & DETAIL AT GRENFELL	REFERENCE 9552
DATE MAY/JUNE 2005 SCALE	SHIRE OF WEDDIN	SHEET OF



GALLAGHER ODELL & GAREY PROJECT MANAGERS/SURVEYORS	CULVERT SHAPE & DETAIL AT GRENFELL	REFERENCE 9552
DATE: MAY/JUNE 2005	SHIRE OF WEDDIN	SHEET OF

SKETCH 130





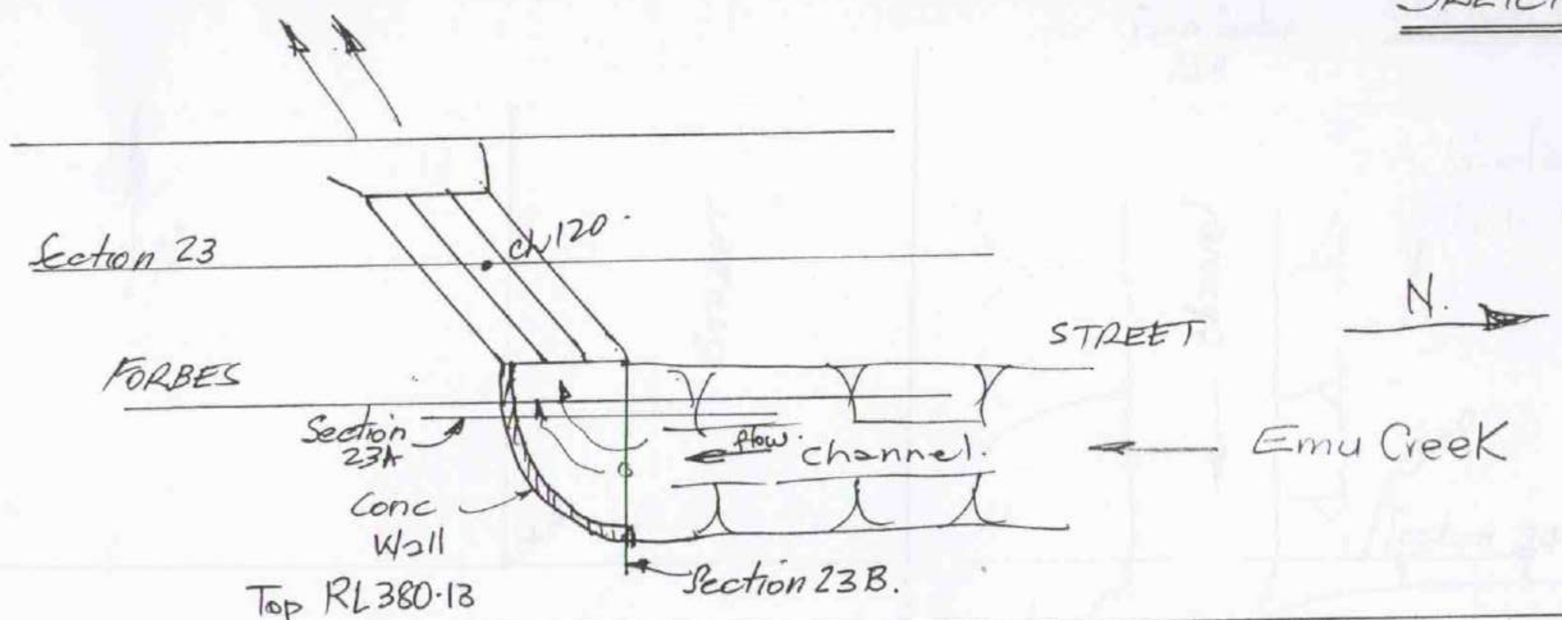
GALLAGHER ODELL & GAREY
PROJECT MANAGERS/SURVEYORS

CULVERT SHAPE & DETAIL
AT GRENFELL
SHIRE OF WEDDIN

REFERENCE 9552

DATE: MAY/JUNE 2005

SKETCH 131

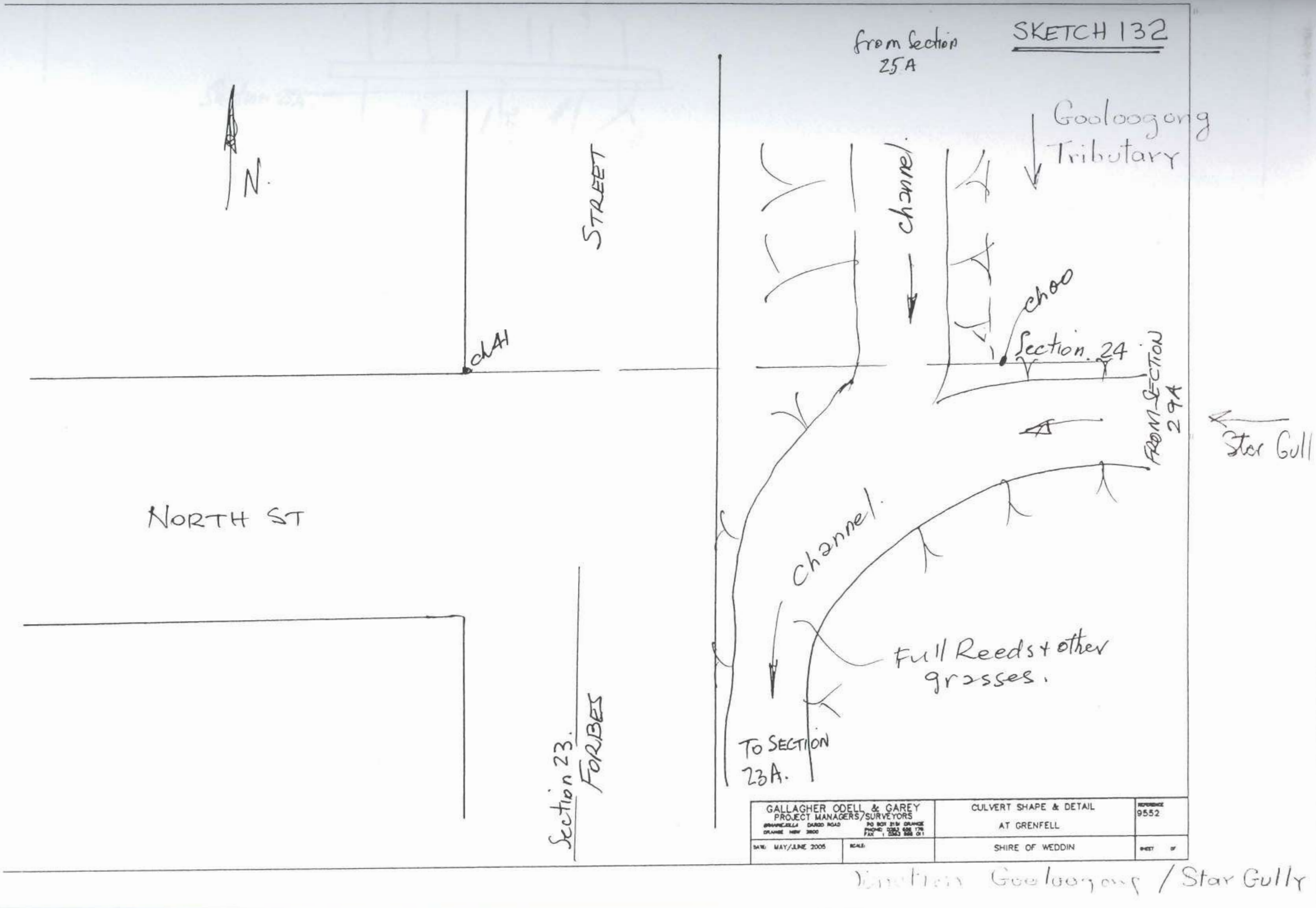


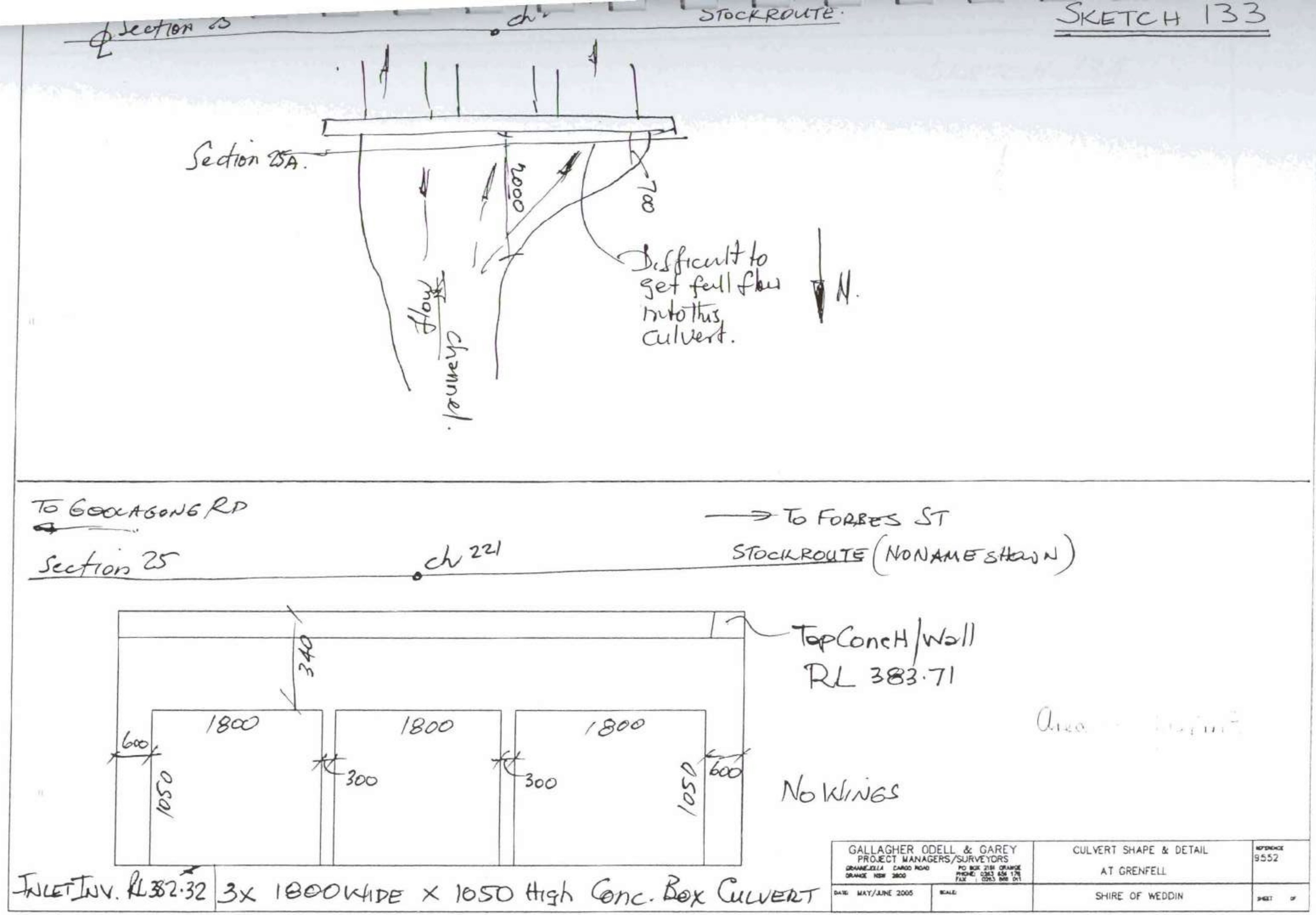
XSA = Cross Sectional Area.

All culvert dimensions perp. to walls of culvert

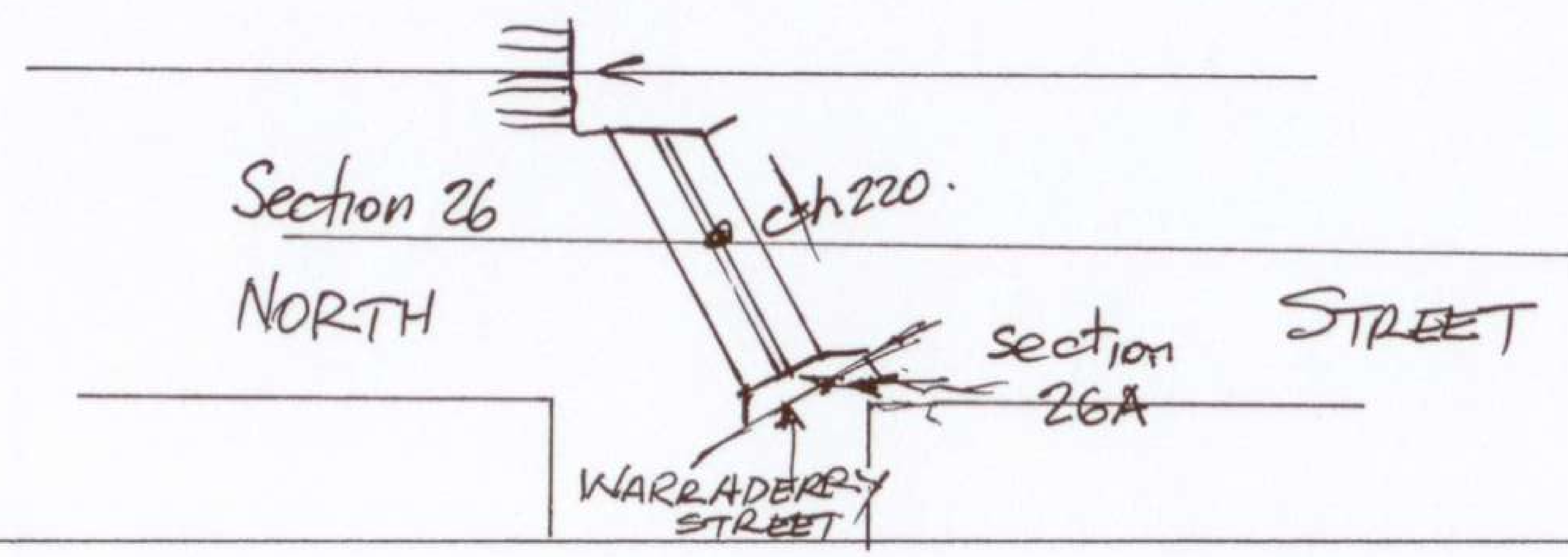
2 x LARGE ELIPTICAL CULVERTS.

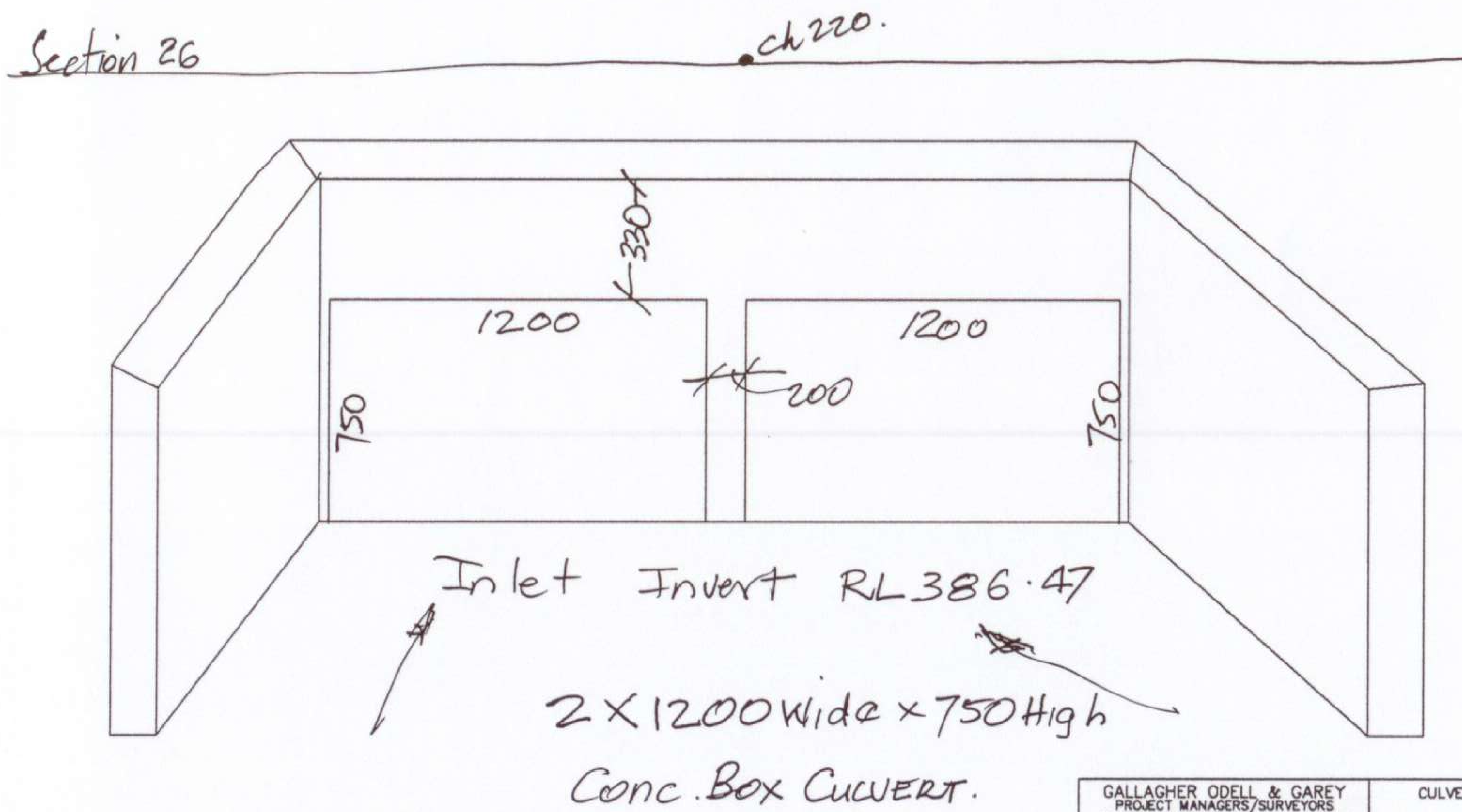
GALLAGHER ODELL & GAREY PROJECT MANAGERS/SURVEYORS	CULVERT SHAPE & DETAIL AT GRENFELL	REFERENCE 9552
DATE MAY/JUNE 2008	SHIRE OF WEDDIN	SHEET OF


SKETCH 132
from Section 25A
Gooloogong Tributary
channel
choo
Section 24
FROM SECTION 29A
Star Gull
N.
STREET
chA1
NORTH ST
channel.
Full Reeds + other grasses.
TO SECTION 23A.
Section 23.
FORBES
GALLAGHER ODELL & GAREY
PROJECT MANAGERS/SURVEYORS
CULVERT SHAPE & DETAIL
AT GRENFELL
SHIRE OF WEDDIN
9552
DATE: MAY/JUNE 2005
Junction Gooloogong / Star Gully

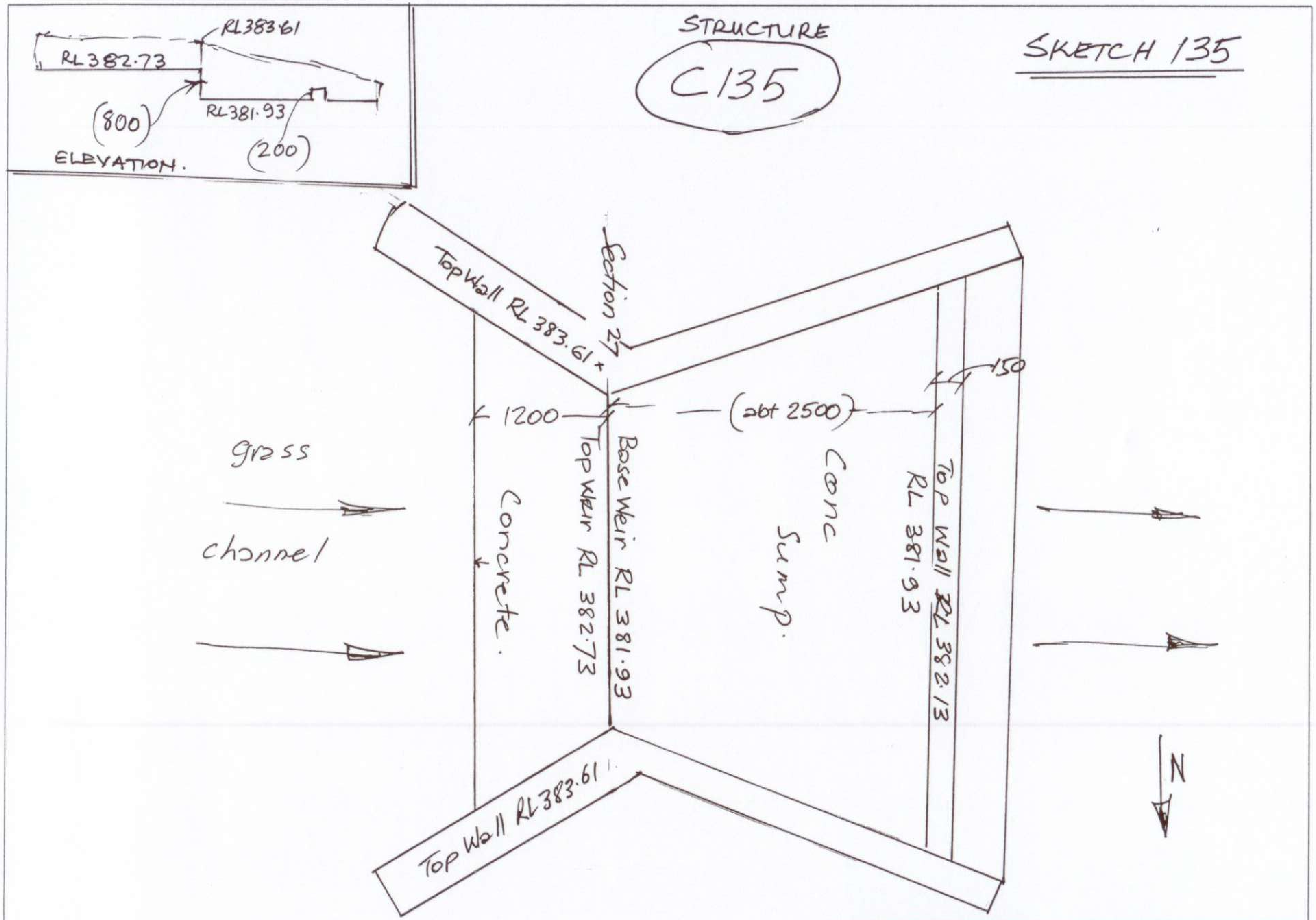

SKETCH 133
Section 25
ch
STOCKROUTE.
Section 25A.
2000
700
flow
channel.
Difficult to get full flow into this culvert.
N.
TO GOOLAGONG RD
→ TO FORBES ST
Section 25
ch 221
STOCKROUTE (NO NAME SHOWN)
340
Top Conc H/Wall
RL 383.71
1800
1800
1800
600
300
300
600
1050
1050
No WINGS
INLET INV. RL 382.32
3x 1800 WIDE × 1050 High Conc. Box CULVERT
GALLAGHER ODELL & GAREY
PROJECT MANAGERS/SURVEYORS
CULVERT SHAPE & DETAIL
AT GRENFELL
SHIRE OF WEDDIN
REFERENCE 9552
DATE MAY/JUNE 2005
SCALE
SHEET OF

SKETCH 134.



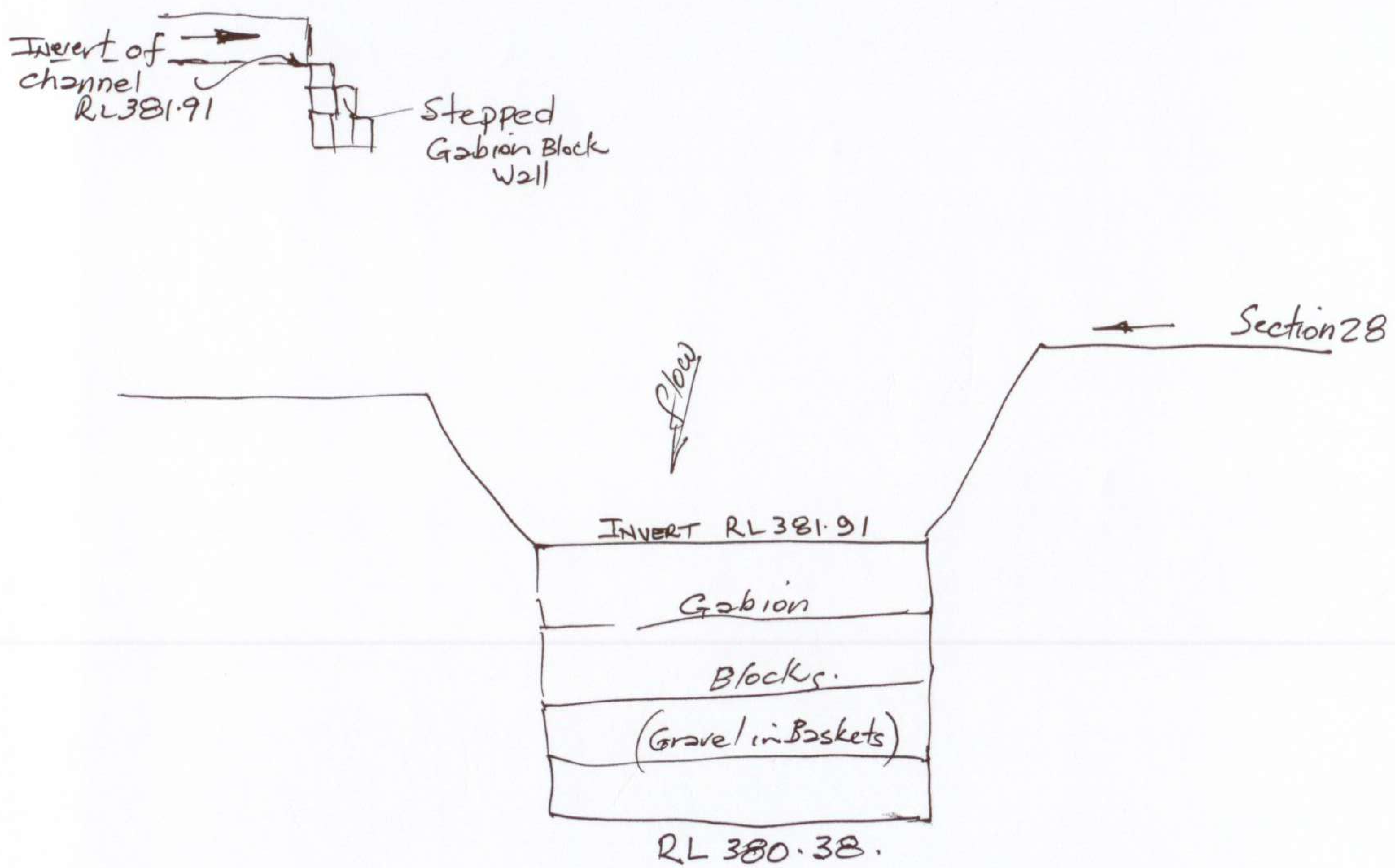


GALLAGHER ODELL & GAREY PROJECT MANAGERS/SURVEYORS	CULVERT SHAPE & DETAIL AT GRENFELL	REFERENCE 9552
DATE MAY/JUNE 2005 SCALE	SHIRE OF WEDDIN	SHEET OF



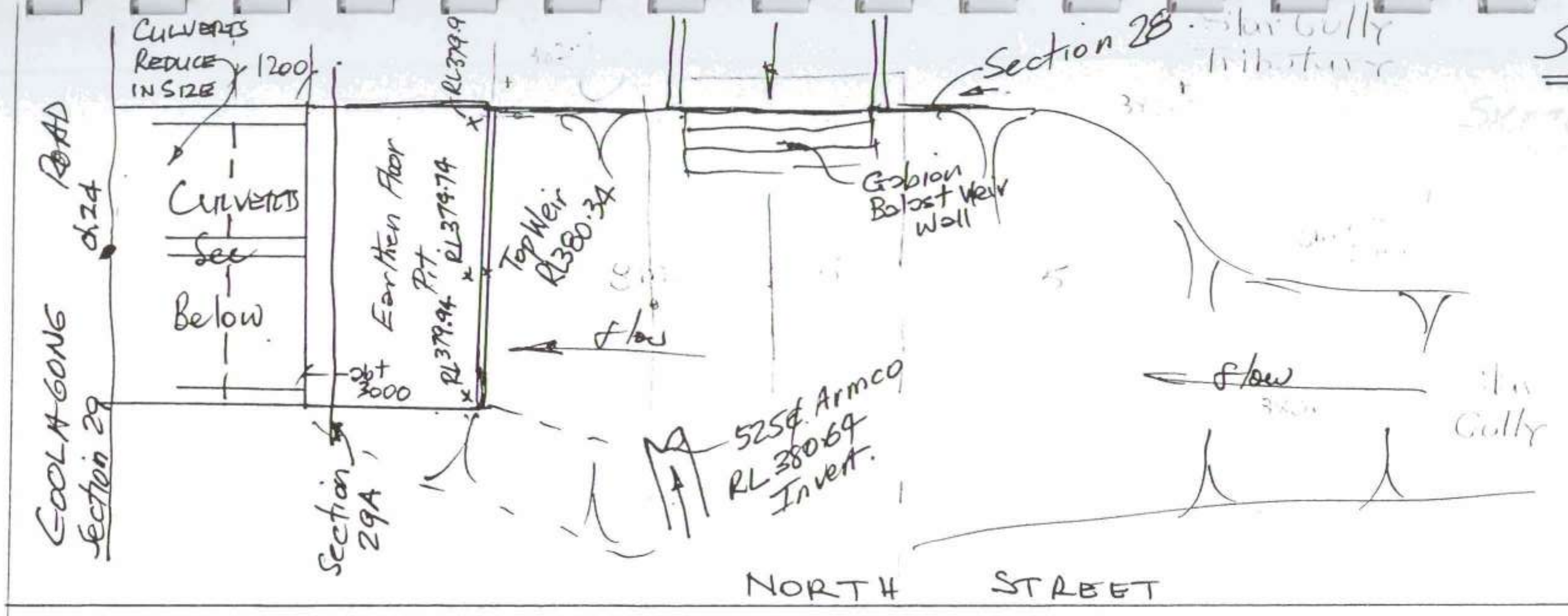
GALLAGHER ODELL & GAREY PROJECT MANAGERS/SURVEYORS GRANNEJOLLA CARGO ROAD ORANGE NSW 2800 PO BOX 3151 ORANGE PHONE: 0263 [illegible] FAX: 0263 [illegible]	CULVERT SHAPE & DETAIL AT GRENFELL	REFERENCE 9552
DATE: MAY/JUNE 2005 SCALE:	SHIRE OF WEDDIN	SHEET OF

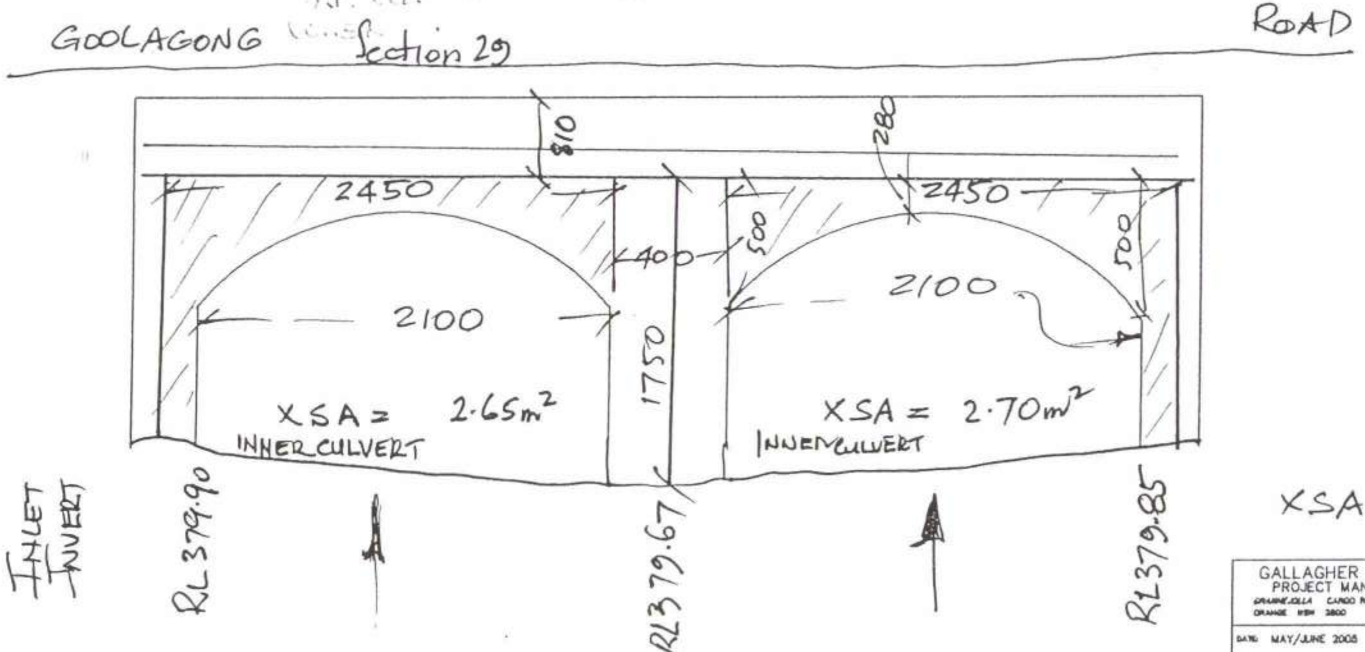
SKETCH 136



GALLAGHER ODELL & GAREY PROJECT MANAGERS/SURVEYORS	CULVERT SHAPE & DETAIL AT GRENFELL	REFERENCE 9552
DATE MAY/JUNE 2005 | SCALE	SHIRE OF WEDDIN	SHEET OF

SKETCH 137





NOTE !!!

FIRST 1200mm

2 X 2450 WIDE X 1750 High (Variable)

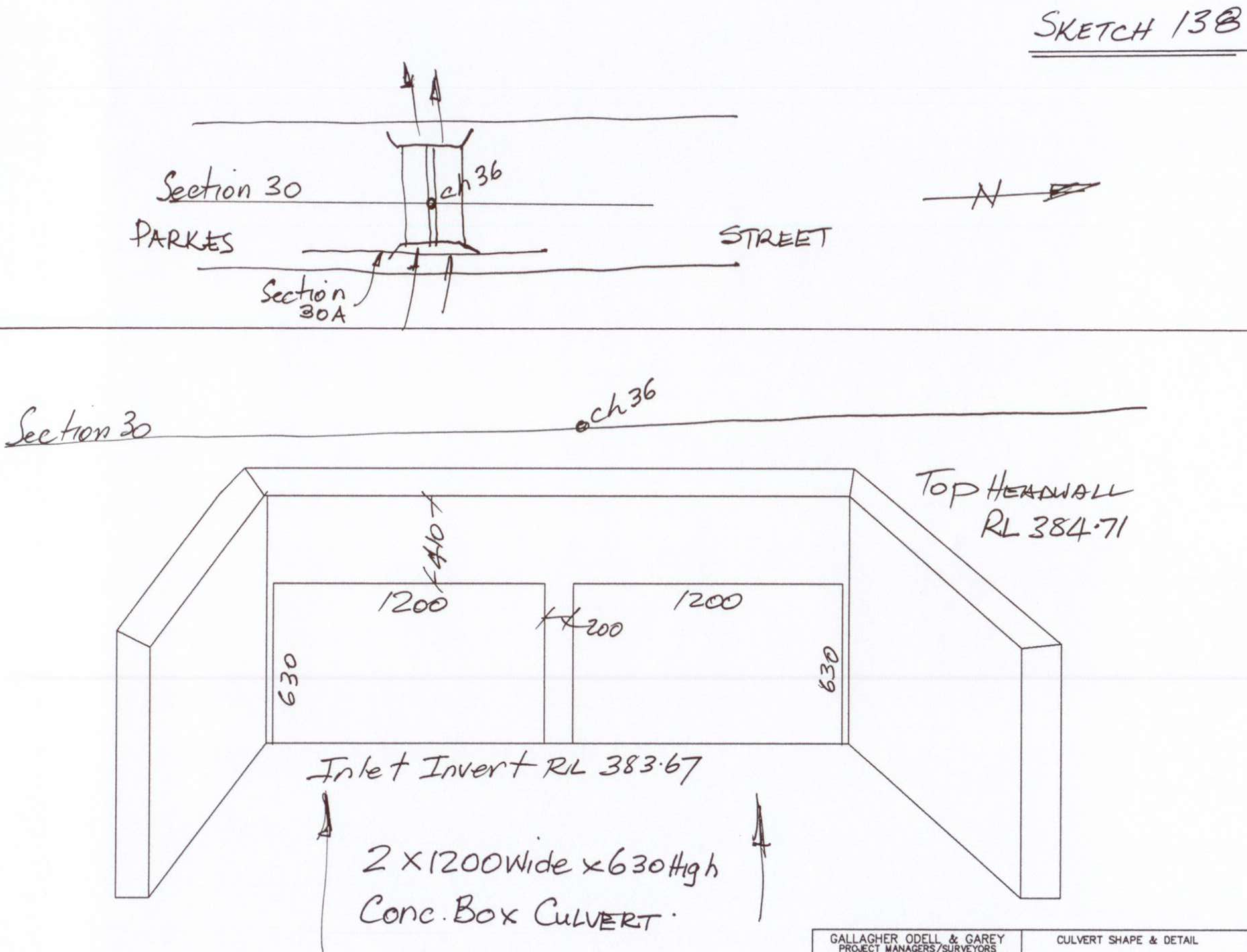
Conc. Box Culverts

THEN:

2 X LARGE ELIPTICAL BOX CULVERTS

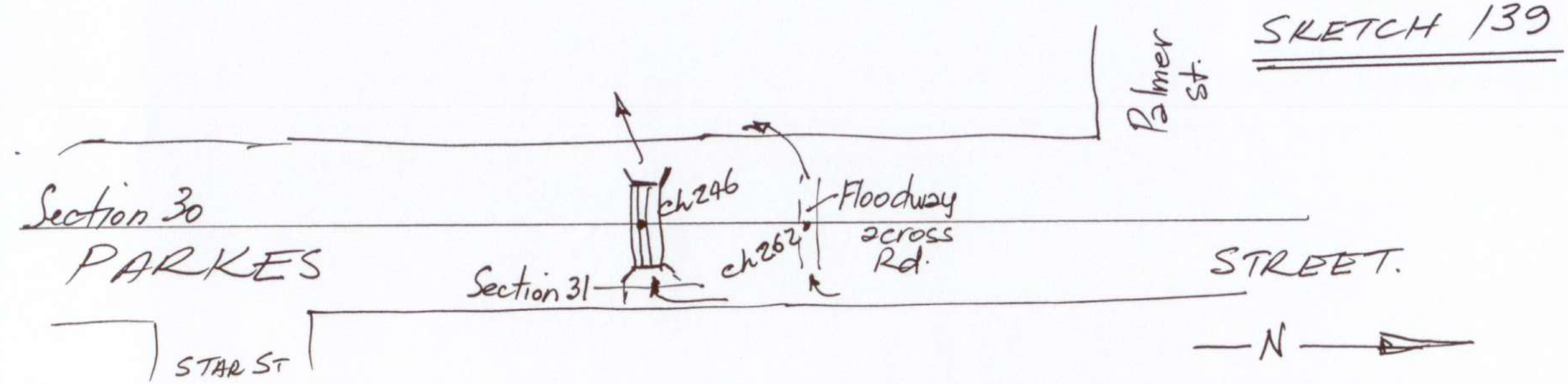
XSA = CROSS SECTIONAL AREA

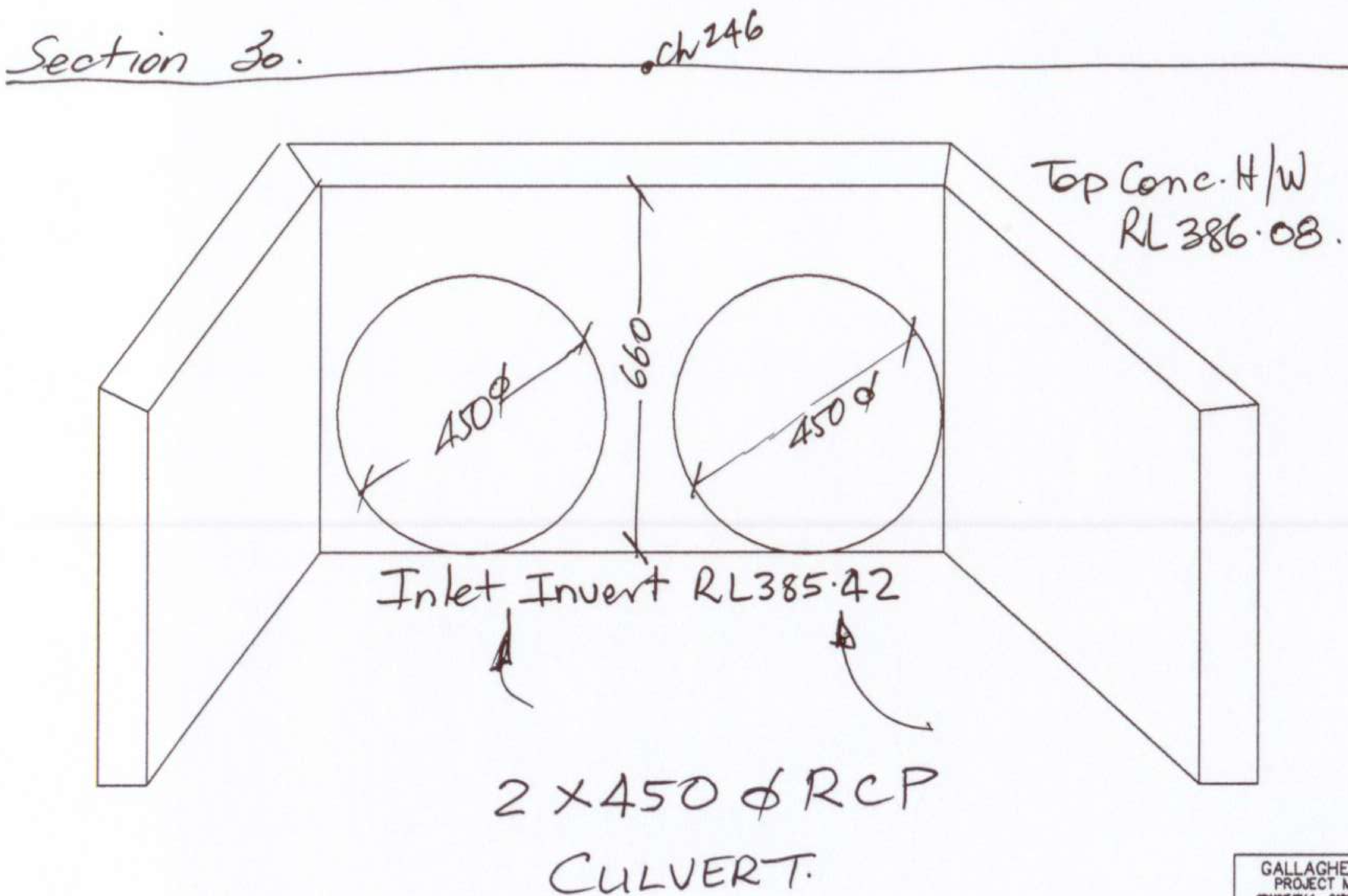
GALLAGHER ODELL & GAREY PROJECT MANAGERS/SURVEYORS	CULVERT SHAPE& DETAIL AT GRENFELL	REFERENCE 9552
DATE MAY/JUNE 2005	SHIRE OF WEDDIN	SHEET



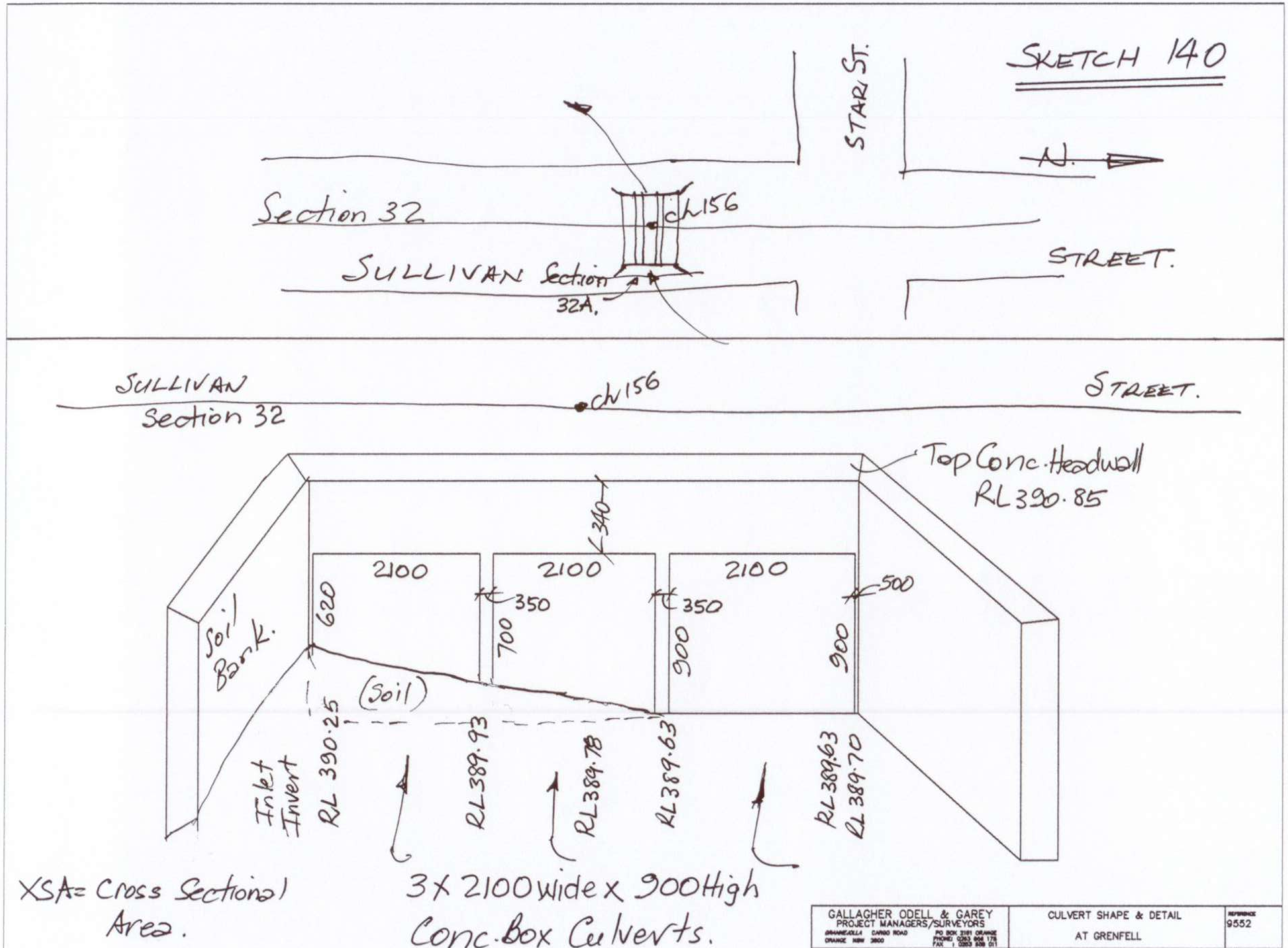
GALLAGHER ODELL & GAREY PROJECT MANAGERS/SURVEYORS	CULVERT SHAPE & DETAIL AT GRENFELL	REFERENCE 9552
DATE MAY/JUNE 2005 SCALE	SHIRE OF WEDDIN	SHEET OF

SKETCH 139



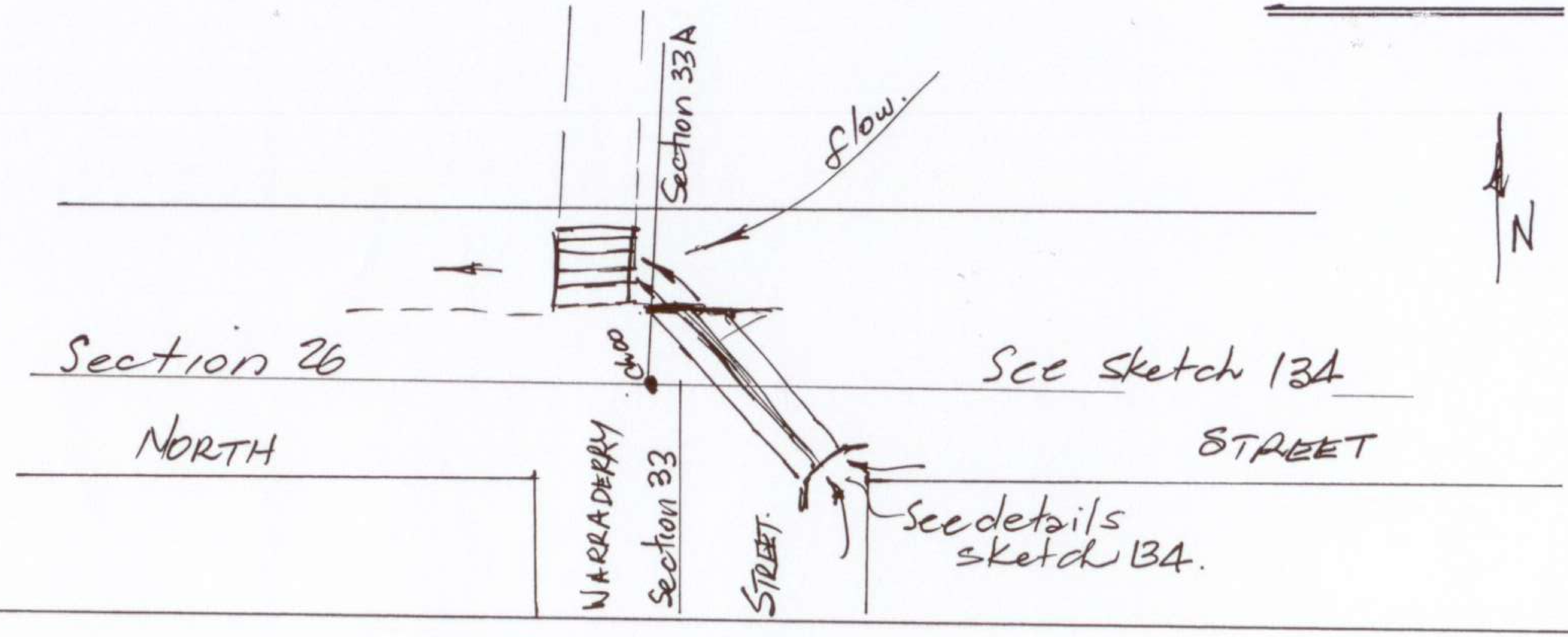


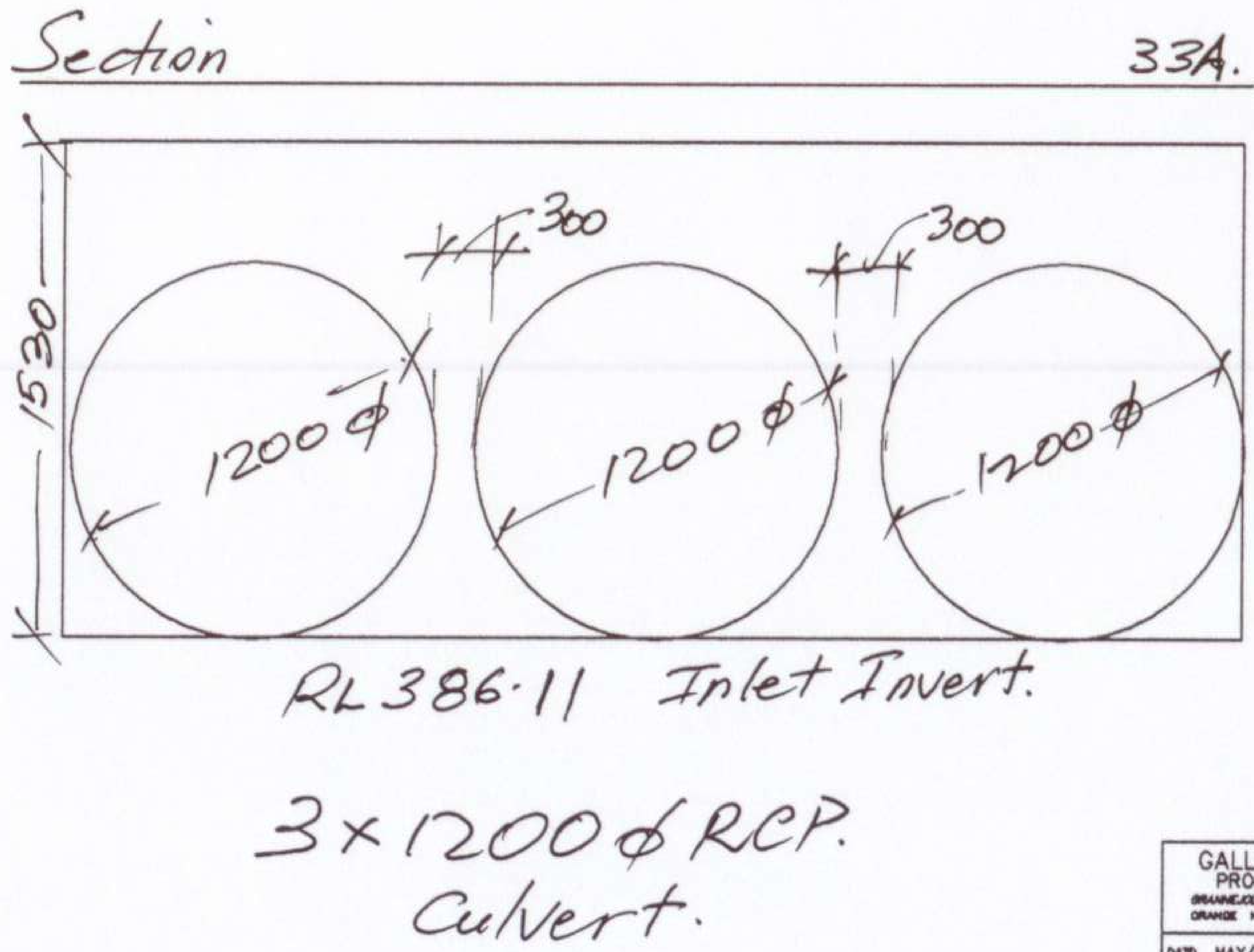
GALLAGHER ODELL & GAREY PROJECT MANAGERS/SURVEYORS	CULVERT SHAPE & DETAIL AT GRENFELL	REFERENCE 9552
DATE: MAY/JUNE 2005 — SCALE:	SHIRE OF WEDDIN	SHEET OF



GALLAGHER ODELL & GAREY PROJECT MANAGERS/SURVEYORS	CULVERT SHAPE & DETAIL AT GRENFELL	REFERENCE 9552
DATE MAY/JUNE 2005	SHIRE OF WEDDIN	SHEET OF

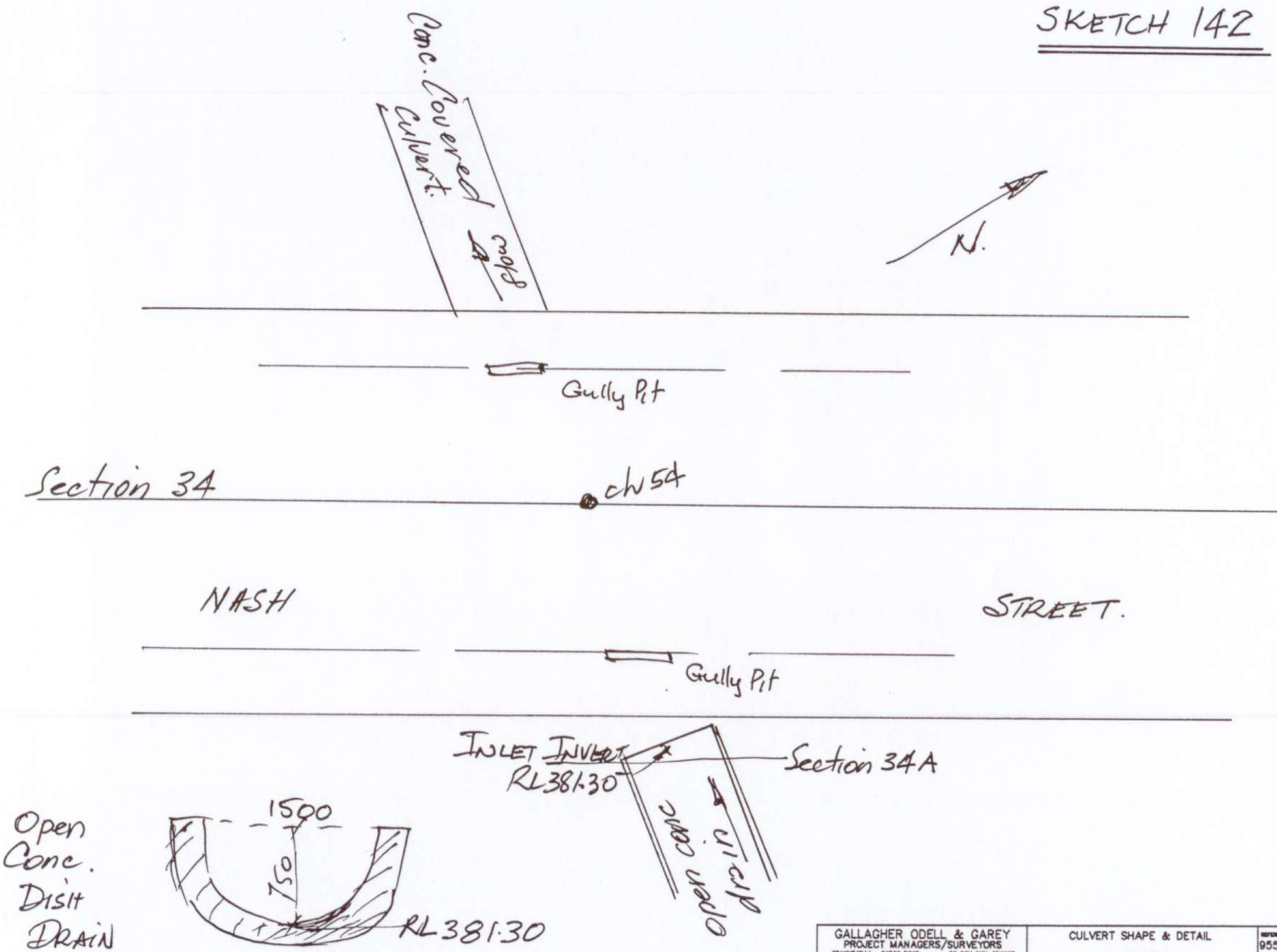
SKETCH 141





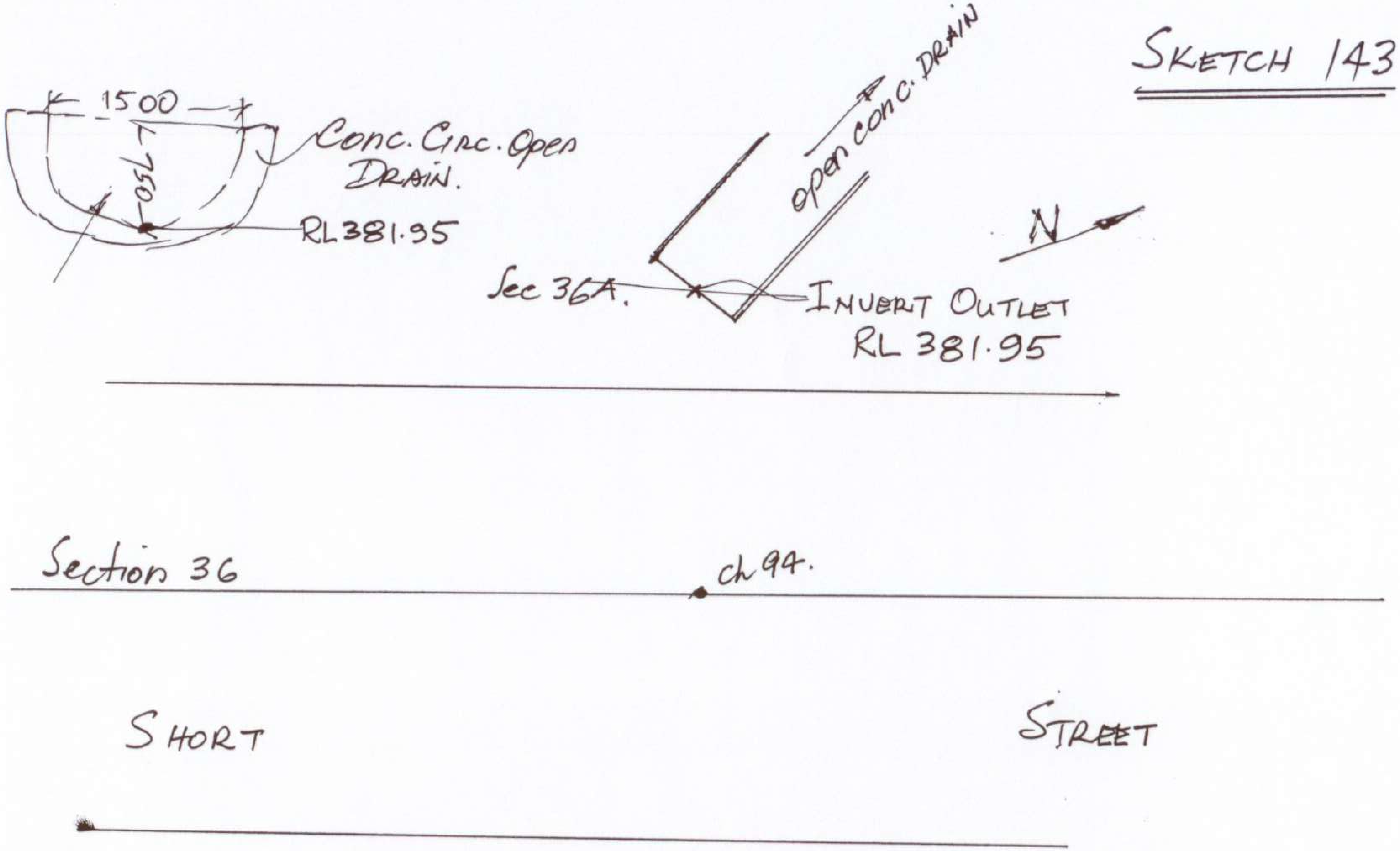
GALLAGHER ODELL & GAREY PROJECT MANAGERS/SURVEYORS	CULVERT SHAPE & DETAIL AT GRENFELL	REFERENCE 9552
DATE: MAY/JUNE 2006 · SCALE:	SHIRE OF WEDDIN	SHEET OF

SKETCH 142



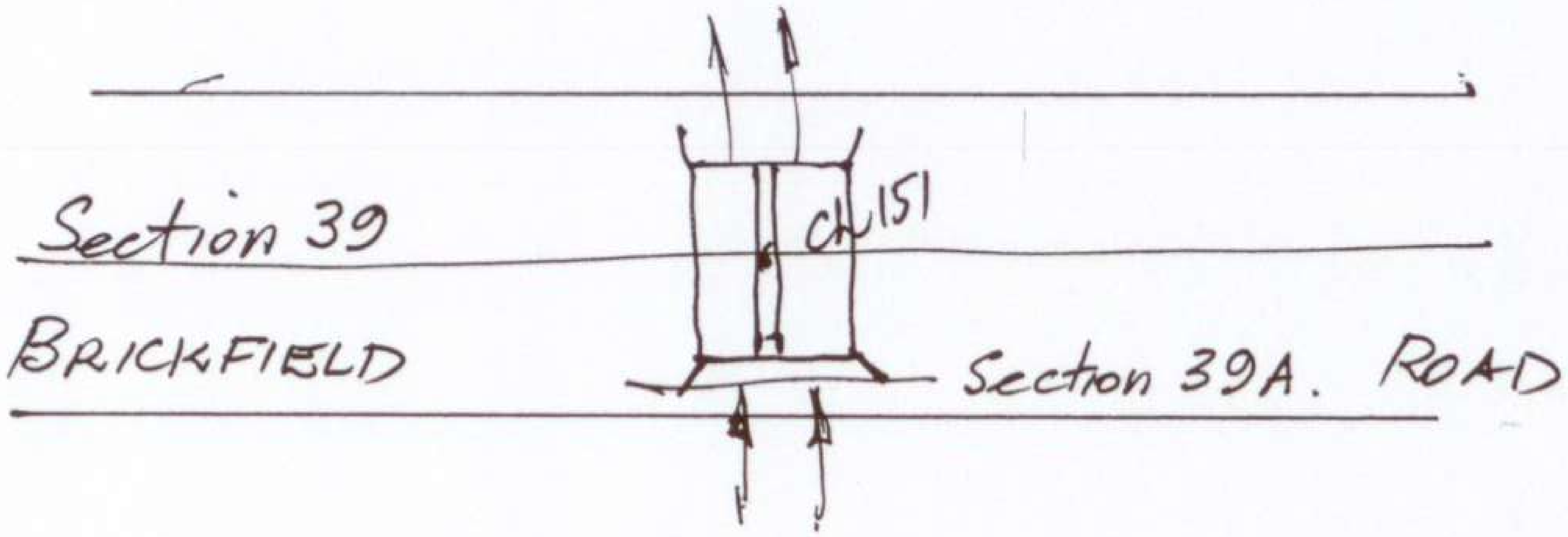
GALLAGHER ODELL & GAREY PROJECT MANAGERS/SURVEYORS	CULVERT SHAPE & DETAIL AT GRENFELL	REFERENCE 9552
DATE MAY/JUNE 2005 SCALE	SHIRE OF WEDDIN	SHEET OF

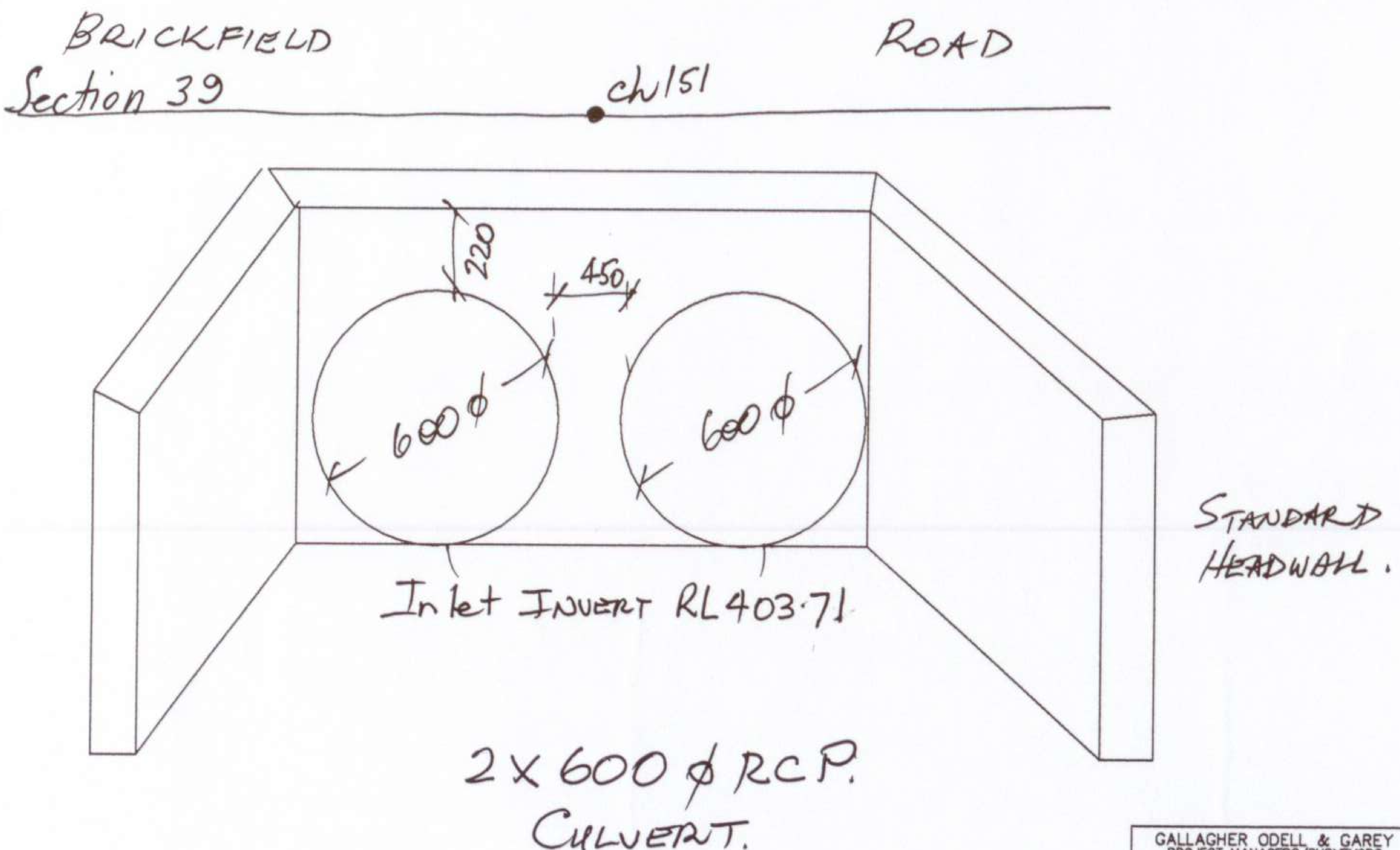
SKETCH 143



GALLAGHER ODELL & GAREY PROJECT MANAGERS/SURVEYORS	CULVERT SHAPE & DETAIL AT GRENFELL	REFERENCE 9552
DATE MAY/JUNE 2005 — SCALE	SHIRE OF WEDDIN	SHEET OF

SKETCH 144

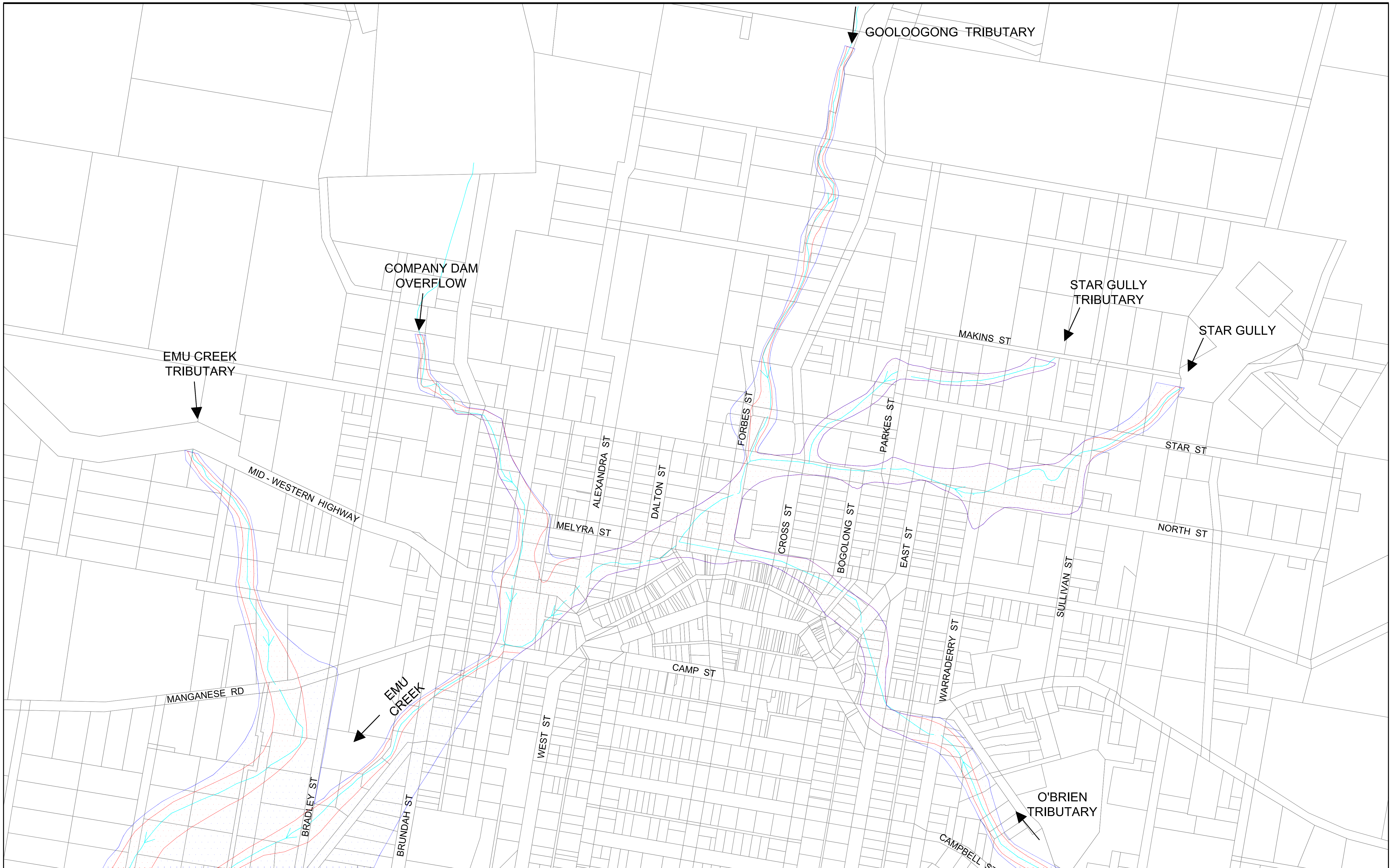




GALLAGHER ODELL & GAREY PROJECT MANAGERS/SURVEYORS GRANNIEZELLA CARGO ROAD ORANGE NSW 2800 PO BOX 3131 ORANGE PHONE 0263 666 176 FAX 0263 666 011	CULVERT SHAPE & DETAIL AT GRENFELL	REFERENCE 9552
DATE MAY/JUNE 2006 SCALE	SHIRE OF WEDDIN	SHEET OF

APPENDIX B

PROVISIONAL HYDRAULIC AND HAZARD CATEGORIES
100 YEAR ARI FLOOD

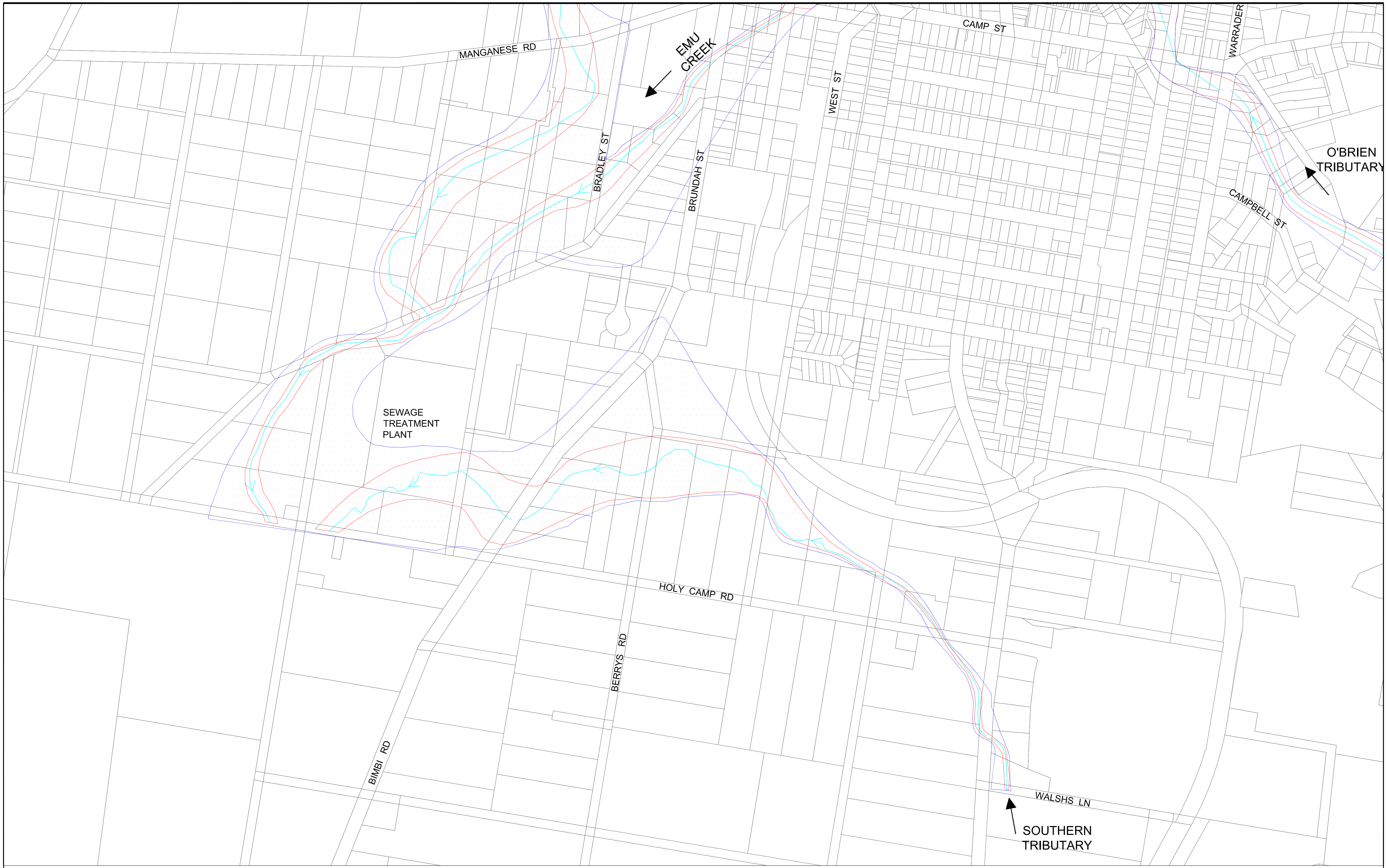


LEGEND

- FLOODWAY EXTENT
- FLOOD STORAGE AREA
- APPROXIMATE LINE OF STREAM INVERT

EMU CREEK FLOOD STUDY

FIGURE B1
SHEET 1 OF 2
EXTENT OF 100 YEAR ARI FLOODWAY



LEGEND

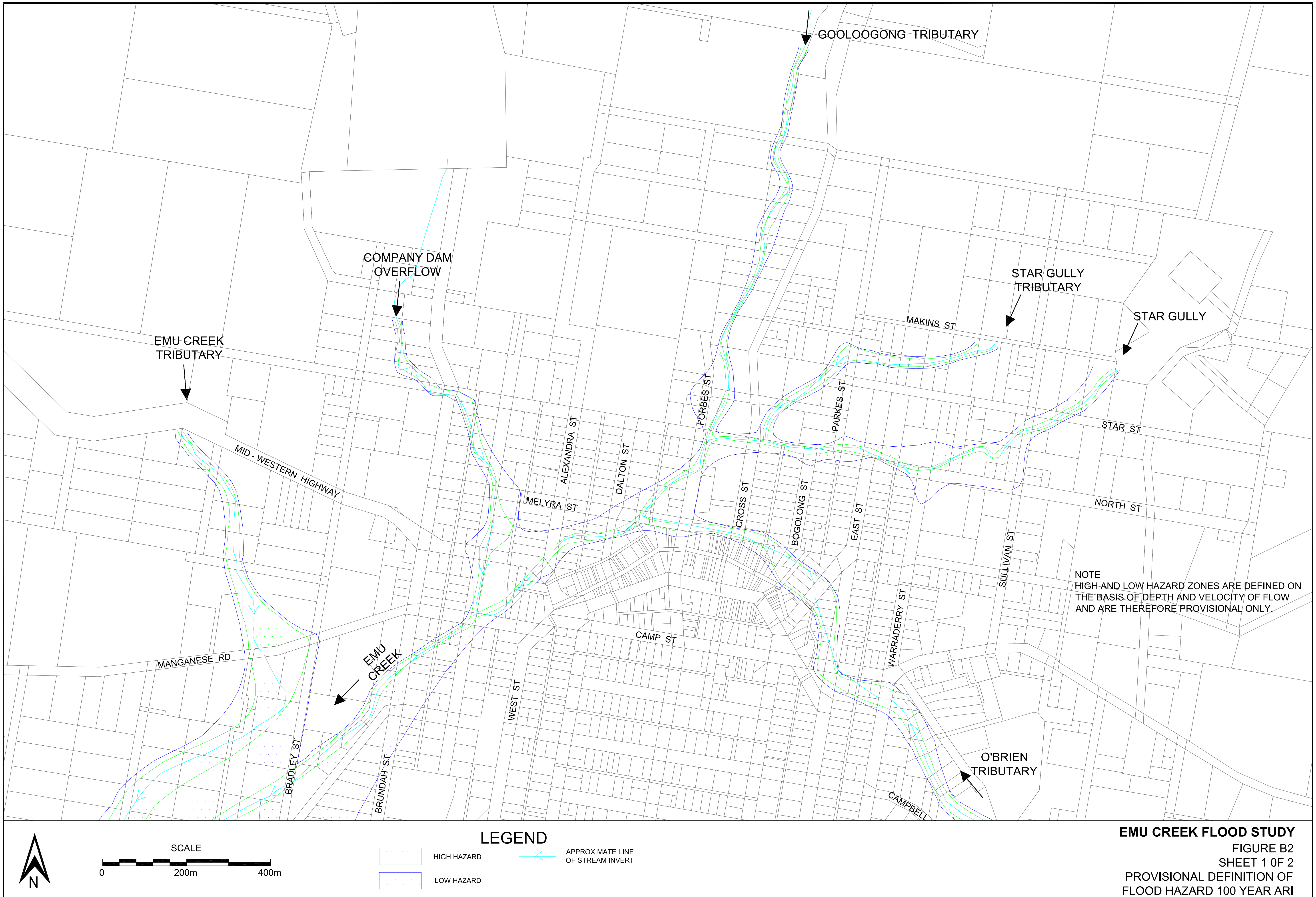
FLOODWAY EXTENT

FLOOD STORAGE AREA

APPROXIMATE LINE OF STREAM INVERT

EMU CREEK FLOOD STUDY

FIGURE B1
SHEET 2 OF 2
EXTENT OF 100 YEAR ARI FLOODWAY

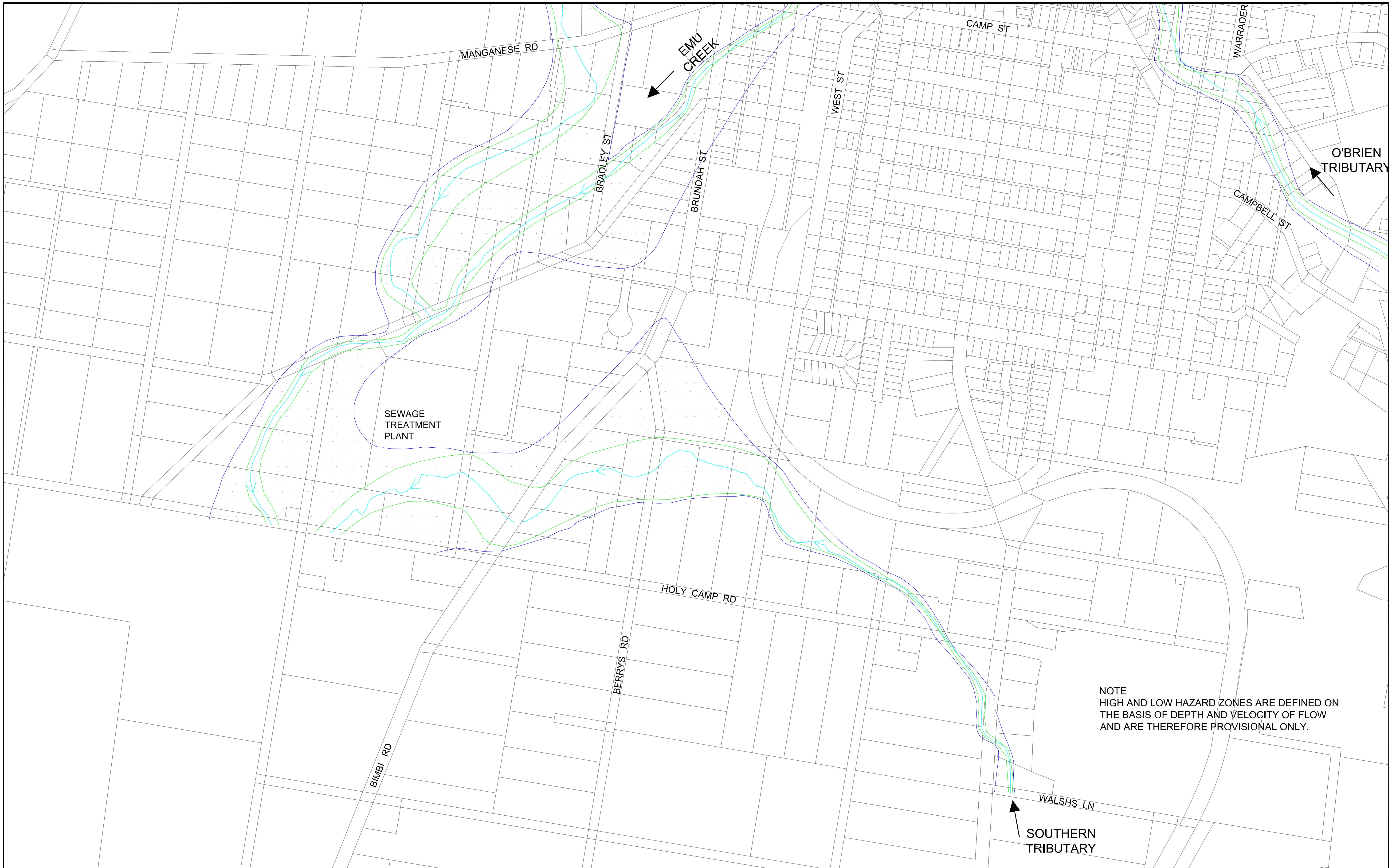


EMU CREEK FLOOD STUDY

FIGURE B2

SHEET 1 0F 2

PROVISIONAL DEFINITION OF FLOOD HAZARD 100 YEAR ARI



LEGEND

- HIGH HAZARD
- LOW HAZARD
- APPROXIMATE LINE OF STREAM INVERT

EMU CREEK FLOOD STUDY

FIGURE B2

SHEET 2 0F 2

PROVISIONAL DEFINITION OF FLOOD HAZARD 100 YEAR ARI

APPENDIX C

FLOOD LEVEL, FLOW AND VELOCITY DISTRIBUTION TABULATIONS - DESIGN FLOODS

River	Reach	River Station	Profile	Q Total	Q Left	Q Channel	Q Right	Vel Left	Vel Chnl	Vel Right	W.S. Elev
				(m3/s)	(m3/s)	(m3/s)	(m3/s)	(m/s)	(m/s)	(m/s)	(m)
Star Gully	Star Gully	1126	20yr	6.4		0.26	6.14		0.05	0.12	394.57
Star Gully	Star Gully	1126	50yr	11.5		0.46	11.04		0.09	0.22	394.57
Star Gully	Star Gully	1126	100yr	16.1		0.64	15.46		0.13	0.31	394.57
Star Gully	Star Gully	1126	200yr	19		0.76	18.24		0.15	0.36	394.57
Star Gully	Star Gully	1126	PMF	76		14.65	61.35		0.58	0.74	394.82
				Star St							
Star Gully	Star Gully	906	20yr	6.4		6.4			7.4		391.23
Star Gully	Star Gully	906	50yr	11.5		11.5			6.58		391.26
Star Gully	Star Gully	906	100yr	16.1		9.46	6.64		1.3	1.26	391.41
Star Gully	Star Gully	906	200yr	19		13.12	5.88		4.5	3.42	391.3
Star Gully	Star Gully	906	PMF	76	0.19	44.15	31.66	0.49	1.98	2.1	391.71
Star Gully	Star Gully	850	20yr	6.4		6.4			1.26		390.51
Star Gully	Star Gully	850	50yr	11.5	9.34	2.16	0	0.17	0.23	0.05	391
Star Gully	Star Gully	850	100yr	16.1	13.12	2.98	0	0.23	0.32	0.06	391
Star Gully	Star Gully	850	200yr	19	15.42	3.57	0.01	0.28	0.38	0.07	391
Star Gully	Star Gully	850	PMF	76	65.42	10.49	0.1	0.81	0.97	0.13	391.16
Star Gully	Star Gully	845		**Sullivan St**							
Star Gully	Star Gully	840	20yr	6.4		6.4			1.38		390.45
Star Gully	Star Gully	840	50yr	11.5	0.01	11.49	0	0.27	1.35	0.18	390.9
Star Gully	Star Gully	840	100yr	16.1	13.03	3.06	0	0.24	0.33	0.06	390.99
Star Gully	Star Gully	840	200yr	19	15.38	3.61	0.01	0.28	0.39	0.07	390.99
Star Gully	Star Gully	840	PMF	76	64.95	10.99	0.06	0.85	1.04	0.13	391.13
Star Gully	Star Gully	598	20yr	6.4	0.1	6.3	0	0.28	1.25	0.08	387.82
Star Gully	Star Gully	598	50yr	11.5	0.22	11.28	0	0.53	2.21	0.18	387.83
Star Gully	Star Gully	598	100yr	16.1	1.11	14.63	0.36	0.94	2.31	0.66	387.99
Star Gully	Star Gully	598	200yr	19	1.66	16.66	0.68	1.1	2.43	0.85	388.05
Star Gully	Star Gully	598	PMF	76	13.79	52.94	9.27	2.51	4	2.32	388.85

River	Reach	River Station	Profile	Q Total	Q Left	Q Channel	Q Right	Vel Left	Vel Chnl	Vel Right	W.S. Elev
				(m3/s)	(m3/s)	(m3/s)	(m3/s)	(m/s)	(m/s)	(m/s)	(m)
Star Gully	Star Gully	520	20yr	6.4		6.4			0.79		387.45
Star Gully	Star Gully	520	50yr	11.5	6.05	3.81	1.64	0.21	0.32	0.12	387.73
Star Gully	Star Gully	520	100yr	16.1	8.54	4.96	2.61	0.27	0.4	0.16	387.78
Star Gully	Star Gully	520	200yr	19	10.1	5.66	3.24	0.3	0.45	0.19	387.8
Star Gully	Star Gully	520	PMF	76	41.08	16.33	18.59	0.72	1.02	0.51	388.06
Star Gully	Star Gully	518		**Warraderry St.**							
Star Gully	Star Gully	516	20yr	6.4		6.4			1.19		387.16
Star Gully	Star Gully	516	50yr	11.5		11.5			1.34		387.49
Star Gully	Star Gully	516	100yr	16.1		14.06	2.04		1.42	0.37	387.59
Star Gully	Star Gully	516	200yr	19		15.45	3.55		1.48	0.46	387.64
Star Gully	Star Gully	516	PMF	76	40.48	22.14	13.38	1.17	1.74	0.73	387.81
				East St							
Star Gully	Star Gully	395.3	20yr	6.4		6.4			1.55		385.22
Star Gully	Star Gully	395.3	50yr	11.5		11.5			1.66		385.35
Star Gully	Star Gully	395.3	100yr	16.1		16.1			1.75		385.43
Star Gully	Star Gully	395.3	200yr	19		19			1.79		385.47
Star Gully	Star Gully	395.3	PMF	76	1.4	68.77	5.83	0.72	2.29	0.83	385.98
Star Gully	Star Gully	320	20yr	8.8		8.8			0.41		384.83
Star Gully	Star Gully	320	50yr	15.4	0.03	15.37		0.13	0.59		384.98
Star Gully	Star Gully	320	100yr	21.5	0.1	21.4		0.21	0.78		385.02
Star Gully	Star Gully	320	200yr	25.4	0.16	25.24		0.26	0.89		385.04
Star Gully	Star Gully	320	PMF	99	15.44	48.33	35.23	0.69	0.89	0.42	385.79
Star Gully	Star Gully	313		**Parkes St**							

River	Reach	River Station	Profile	Q Total	Q Left	Q Channel	Q Right	Vel Left	Vel Chnl	Vel Right	W.S. Elev
				(m3/s)	(m3/s)	(m3/s)	(m3/s)	(m/s)	(m/s)	(m/s)	(m)
Star Gully	Star Gully	309	20yr	8.8		8.8			1.76		384.13
Star Gully	Star Gully	309	50yr	15.4		15.4			1.52		384.4
Star Gully	Star Gully	309	100yr	21.5		21.5			1.5		384.58
Star Gully	Star Gully	309	200yr	25.4		25.4			1.51		384.67
Star Gully	Star Gully	309	PMF	99	15.34	48.89	34.77	0.7	0.91	0.42	385.77
Star Gully	Star Gully	230	20yr	8.8	0.4	8.32	0.08	0.24	1.12	0.19	383.89
Star Gully	Star Gully	230	50yr	15.4	2.85	12.01	0.54	0.49	1.28	0.35	384.2
Star Gully	Star Gully	230	100yr	21.5	4.98	15.55	0.97	0.65	1.52	0.45	384.33
Star Gully	Star Gully	230	200yr	25.4	6.43	17.69	1.28	0.74	1.65	0.51	384.4
Star Gully	Star Gully	230	PMF	99	38.52	52.56	7.92	1.89	3.26	0.89	385.25
				Weir							
Star Gully	Star Gully	228.8	20yr	8.8		8.8			2.79		383.52
Star Gully	Star Gully	228.8	50yr	15.4	2.87	12.02	0.51	0.74	2.31	0.58	384.03
Star Gully	Star Gully	228.8	100yr	21.5	5.77	14.72	1.01	1.01	2.58	0.74	384.15
Star Gully	Star Gully	228.8	200yr	25.4	7.71	16.34	1.35	1.16	2.74	0.83	384.22
Star Gully	Star Gully	228.8	PMF	99	48.5	39.9	10.6	2.67	4.42	1.7	384.99
Star Gully	Star Gully	228.3	20yr	8.8		8.8			5.34		382.34
Star Gully	Star Gully	228.3	50yr	15.4		15.4			5.37		382.65
Star Gully	Star Gully	228.3	100yr	21.5		21.5			5.05		383
Star Gully	Star Gully	228.3	200yr	25.4		25.4			4.66		383.29
Star Gully	Star Gully	228.3	PMF	99	36.39	55.4	7.21	2.63	5.01	1.71	384.69
Star Gully	Star Gully	225.8	20yr	8.8		8.8			4.92		382.18
Star Gully	Star Gully	225.8	50yr	15.4		15.4			5.58		382.31
Star Gully	Star Gully	225.8	100yr	21.5		21.5			5.73		382.45
Star Gully	Star Gully	225.8	200yr	25.4		25.4			5.77		382.54
Star Gully	Star Gully	225.8	PMF	99	14.15	82.32	2.53	2.28	6.15	1.74	383.79

River	Reach	River Station	Profile	Q Total	Q Left	Q Channel	Q Right	Vel Left	Vel Chnl	Vel Right	W.S. Elev
				(m3/s)	(m3/s)	(m3/s)	(m3/s)	(m/s)	(m/s)	(m/s)	(m)
Star Gully	Star Gully	115.8	20yr	8.8		8.8			1.43		381.33
Star Gully	Star Gully	115.8	50yr	15.4		15.4			1.17		382.23
Star Gully	Star Gully	115.8	100yr	21.5	4.3	17.2		0.49	0.96		382.77
Star Gully	Star Gully	115.8	200yr	25.4	6.62	18.78		0.58	0.99		382.9
Star Gully	Star Gully	115.8	PMF	99	48.62	42.05	8.33	1.26	1.37	0.64	384.19
Star Gully	Star Gully Lower	115	20yr	8.8		8.8			4.89		380.67
Star Gully	Star Gully Lower	115	50yr	15.8		15.8			1.21		382.22
Star Gully	Star Gully Lower	115	100yr	21.9	2.52	18.6	0.78	0.27	1.04	0.19	382.76
Star Gully	Star Gully Lower	115	200yr	26	3.77	20.71	1.51	0.32	1.09	0.24	382.89
Star Gully	Star Gully Lower	115	PMF	93	26.79	48.53	17.68	0.71	1.58	0.65	384.2
Star Gully	Star Gully Lower	113	20yr	8.8		8.8			1.72		381.19
Star Gully	Star Gully Lower	113	50yr	15.8		15.8			1.23		382.2
Star Gully	Star Gully Lower	113	100yr	21.9	2.44	18.72	0.73	0.27	1.05	0.18	382.75
Star Gully	Star Gully Lower	113	200yr	26	3.7	20.85	1.46	0.32	1.1	0.24	382.87
Star Gully	Star Gully Lower	113	PMF	93	26.73	48.66	17.61	0.71	1.59	0.65	384.18
Star Gully	Star Gully Lower	112	20yr	8.8		8.8			1.08		381.25
Star Gully	Star Gully Lower	112	50yr	15.8		15.8			1		382.22
Star Gully	Star Gully Lower	112	100yr	21.9		21.9			1.07		382.74
Star Gully	Star Gully Lower	112	200yr	26		26			1.21		382.85
Star Gully	Star Gully Lower	112	PMF	93		93			3.19		383.69
Star Gully	Star Gully Lower	110	20yr	8.8		8.8			0.96		381.26
Star Gully	Star Gully Lower	110	50yr	15.8		15.8			0.94		382.22
Star Gully	Star Gully Lower	110	100yr	21.9	0.41	21.31	0.17	0.15	0.99	0.11	382.74
Star Gully	Star Gully Lower	110	200yr	26	1.2	24.28	0.52	0.24	1.07	0.15	382.86
Star Gully	Star Gully Lower	110	PMF	93	20.47	47.46	25.07	0.75	1.44	0.53	384.01
Star Gully	Star Gully Lower	105		**Cross St**							

River	Reach	River Station	Profile	Q Total	Q Left	Q Channel	Q Right	Vel Left	Vel Chnl	Vel Right	W.S. Elev
				(m3/s)	(m3/s)	(m3/s)	(m3/s)	(m/s)	(m/s)	(m/s)	(m)
Star Gully	Star Gully Lower	100	20yr	8.8		8.8			1.07		381.12
Star Gully	Star Gully Lower	100	50yr	15.8		15.8			1.28		381.68
Star Gully	Star Gully Lower	100	100yr	21.9		21.9			1.48		381.98
Star Gully	Star Gully Lower	100	200yr	26		26			1.59		382.15
Star Gully	Star Gully Lower	100	PMF	93	20.38	41.49	31.14	0.75	1.26	0.66	384
Star Gully	Star Gully Lower	20	20yr	8.8		8.8			0.76		380.97
Star Gully	Star Gully Lower	20	50yr	15.8		15.8			0.99		381.5
Star Gully	Star Gully Lower	20	100yr	21.9	2.63	19.27		0.41	1.03		381.82
Star Gully	Star Gully Lower	20	200yr	26	5.45	20.55	0	0.52	1	0.04	382.02
Star Gully	Star Gully Lower	20	PMF	93	43.1	36.55	13.36	0.88	0.96	0.7	383.94

River	Reach	River Station	Profile	Q Total	Q Left	Q Channel	Q Right	Vel Left	Vel Chnl	Vel Right	W.S. Elev
				(m3/s)	(m3/s)	(m3/s)	(m3/s)	(m/s)	(m/s)	(m/s)	(m)
				Makins St.							
Star Gully Tributary	Star Gully Trib.	712	20yr	1.6		1.6			0.71		391.42
Star Gully Tributary	Star Gully Trib.	712	50yr	2.6		2.6			0.82		391.44
Star Gully Tributary	Star Gully Trib.	712	100yr	3.5		3.5			0.93		391.46
Star Gully Tributary	Star Gully Trib.	712	200yr	4.2		4.2			0.97		391.47
Star Gully Tributary	Star Gully Trib.	712	PMF	18.5		18.5			0.86		391.74
Star Gully Tributary	Star Gully Trib.	612	20yr	1.6	1.56	0.04		0.05	0.04		391
Star Gully Tributary	Star Gully Trib.	612	50yr	2.6	2.54	0.06		0.07	0.06		391
Star Gully Tributary	Star Gully Trib.	612	100yr	3.5	3.42	0.08		0.1	0.08		391
Star Gully Tributary	Star Gully Trib.	612	200yr	4.2	4.1	0.1		0.12	0.1		391
Star Gully Tributary	Star Gully Trib.	612	PMF	18.5	18.06	0.44		0.53	0.44		391
				XS-57							
Star Gully Tributary	Star Gully Trib.	442	20yr	1.6		1.6			7.61		387.73
Star Gully Tributary	Star Gully Trib.	442	50yr	2.6		2.6			7.49		387.79
Star Gully Tributary	Star Gully Trib.	442	100yr	3.5		3.5			7.37		387.84
Star Gully Tributary	Star Gully Trib.	442	200yr	4.2		4.2			7.27		387.88
Star Gully Tributary	Star Gully Trib.	442	PMF	18.5	17.68	0.82		0.83	0.82		388
Star Gully Tributary	Star Gully Trib.	345	20yr	1.6		1.52	0.08		0.23	0.08	385.92
Star Gully Tributary	Star Gully Trib.	345	50yr	2.6		2.43	0.17		0.33	0.12	385.96
Star Gully Tributary	Star Gully Trib.	345	100yr	3.5		3.19	0.31		0.38	0.14	386.02
Star Gully Tributary	Star Gully Trib.	345	200yr	4.2		3.81	0.39		0.45	0.17	386.03
Star Gully Tributary	Star Gully Trib.	345	PMF	18.5		13.81	4.69		0.82	0.35	386.46
Star Gully Tributary	Star Gully Trib.	340		**Parkes St**							

River	Reach	River Station	Profile	Q Total	Q Left	Q Channel	Q Right	Vel Left	Vel Chnl	Vel Right	W.S. Elev
				(m3/s)	(m3/s)	(m3/s)	(m3/s)	(m/s)	(m/s)	(m/s)	(m)
Star Gully Tributary	Star Gully Trib.	335	20yr	1.6		1.58	0.02		0.35	0.07	385.81
Star Gully Tributary	Star Gully Trib.	335	50yr	2.6		2.52	0.08		0.42	0.11	385.89
Star Gully Tributary	Star Gully Trib.	335	100yr	3.5		3.42	0.08		0.62	0.16	385.86
Star Gully Tributary	Star Gully Trib.	335	200yr	4.2		4.06	0.14		0.66	0.18	385.9
Star Gully Tributary	Star Gully Trib.	335	PMF	18.5		14.49	4.01		0.87	0.31	386.45
Star Gully Tributary	Star Gully Trib.	225	20yr	1.6		1.18	0.42		1.15	0.86	384.43
Star Gully Tributary	Star Gully Trib.	225	50yr	2.6		1.92	0.68		1.27	0.95	384.48
Star Gully Tributary	Star Gully Trib.	225	100yr	3.5		2.58	0.92		0.5	0.37	384.73
Star Gully Tributary	Star Gully Trib.	225	200yr	4.2		3.1	1.1		0.52	0.39	384.76
Star Gully Tributary	Star Gully Trib.	225	PMF	18.5		13.65	4.85		1.89	1.41	384.82
Star Gully Tributary	Star Gully Trib.	108	20yr	1.6		1.6			0.31		383.18
Star Gully Tributary	Star Gully Trib.	108	50yr	3.5		3.5			0.37		383.29
Star Gully Tributary	Star Gully Trib.	108	100yr	3.5		3.5			1.12		383.11
Star Gully Tributary	Star Gully Trib.	108	200yr	4.2		4.2			1.17		383.12
Star Gully Tributary	Star Gully Trib.	108	PMF	18.5		18.5			0.2		384.28
				Stock Rte							
Star Gully Tributary	Star Gully Trib.	8	20yr	1.6		1.6			1.35		382.1
Star Gully Tributary	Star Gully Trib.	8	50yr	3.5		3.5			1.72		382.23
Star Gully Tributary	Star Gully Trib.	8	100yr	3.5		2.05	1.45		0.32	0.13	382.81
Star Gully Tributary	Star Gully Trib.	8	200yr	4.2	0.01	2.04	2.15	0.02	0.27	0.14	382.94
Star Gully Tributary	Star Gully Trib.	8	PMF	18.5	10.98	2.06	5.46	0.06	0.11	0.08	384.28

River	Reach	River Station	Profile	Q Total	Q Left	Q Channel	Q Right	Vel Left	Vel Chnl	Vel Right	W.S. Elev
				(m3/s)	(m3/s)	(m3/s)	(m3/s)	(m/s)	(m/s)	(m/s)	(m)
Emu Creek	Emu1	2615	20yr	15		15			1.36		380.9
Emu Creek	Emu1	2615	50yr	27.1		27.1			1.8		381.39
Emu Creek	Emu1	2615	100yr	36.7	1.23	35.47		0.45	2.07		381.64
Emu Creek	Emu1	2615	200yr	44.8	5.56	39.24		0.78	2.06		381.86
Emu Creek	Emu1	2615	PMF	158	68.07	65.53	24.4	1.45	1.77	1.2	383.85
Emu Creek	Emu1	2535	20yr	15		15			2.68		379.5
Emu Creek	Emu1	2535	50yr	27.1		27.1			2.55		380.07
Emu Creek	Emu1	2535	100yr	36.7		36.7			2.22		380.64
Emu Creek	Emu1	2535	200yr	44.8		44.8			2.45		380.8
Emu Creek	Emu1	2535	PMF	158		158			5.19		381.91
Emu Creek	Emu1	2530	20yr	15		13.51	1.49		0.72	0.25	379.66
Emu Creek	Emu1	2530	50yr	27.1	0	22.18	4.92	0.06	0.74	0.28	380.28
Emu Creek	Emu1	2530	100yr	36.7	4.43	24.52	7.74	0.11	0.62	0.24	380.8
Emu Creek	Emu1	2530	200yr	44.8	9.16	26.36	9.28	0.15	0.61	0.24	381
Emu Creek	Emu1	2530	PMF	158	62.54	63.9	31.55	0.4	1.12	0.44	381.79
Emu Creek	Emu1	2525		**Forbes St**							
Emu Creek	Emu1	2520	20yr	15		13.96	1.04		1.02	0.33	379.37
Emu Creek	Emu1	2520	50yr	27.1		23.59	3.51		1.16	0.41	379.74
Emu Creek	Emu1	2520	100yr	36.7	0	29.42	7.27	0.05	1.03	0.39	380.2
Emu Creek	Emu1	2520	200yr	44.8	0.01	35.21	9.59	0.11	1.15	0.43	380.32
Emu Creek	Emu1	2520	PMF	158	37.44	82.85	37.71	0.49	1.79	0.7	381.19
Emu Creek	Emu1	2355	20yr	15		15			1.61		378.28
Emu Creek	Emu1	2355	50yr	27.1		27.1			1.73		378.87
Emu Creek	Emu1	2355	100yr	36.7	3.98	26.11	6.62	0.22	0.9	0.24	380.01
Emu Creek	Emu1	2355	200yr	44.8	5.72	29.34	9.75	0.25	0.97	0.28	380.11
Emu Creek	Emu1	2355	PMF	158	40.67	62.8	54.54	0.59	1.62	0.69	380.81
Emu Creek	Emu1	2352		**Melyra St**							

River	Reach	River Station	Profile	Q Total	Q Left	Q Channel	Q Right	Vel Left	Vel Chnl	Vel Right	W.S. Elev
				(m3/s)	(m3/s)	(m3/s)	(m3/s)	(m/s)	(m/s)	(m/s)	(m)
Emu Creek	Emu1	2345	20yr	15		15			1.38		378.43
Emu Creek	Emu1	2345	50yr	27.1		27.1			1.53		379.05
Emu Creek	Emu1	2345	100yr	36.7	1.26	33.97	1.47	0.24	1.4	0.24	379.6
Emu Creek	Emu1	2345	200yr	44.8	3.03	38.26	3.51	0.3	1.46	0.3	379.76
Emu Creek	Emu1	2345	PMF	158	46.43	65.25	46.32	0.61	1.7	0.72	380.78
Emu Creek	Emu2	2345	20yr	19		19			6.41		377.6
Emu Creek	Emu2	2345	50yr	33.7		33.7			6.22		377.88
Emu Creek	Emu2	2345	100yr	46.9	0.77	45.24	0.89	0.29	1.97	0.29	379.49
Emu Creek	Emu2	2345	200yr	55.6	2.42	50.38	2.8	0.37	2.02	0.37	379.65
Emu Creek	Emu2	2345	PMF	193	54.49	82.77	55.74	0.77	2.2	0.91	380.72
Emu Creek	Emu2	2270	20yr	19		19			1.32		377.65
Emu Creek	Emu2	2270	50yr	33.7		33.7			1.21		378.67
Emu Creek	Emu2	2270	100yr	46.9		46.9			1.3		379.28
Emu Creek	Emu2	2270	200yr	55.6	1.9	53.7	0	0.19	1.41	0.02	379.41
Emu Creek	Emu2	2270	PMF	193	57.3	117.07	18.64	0.91	2.32	0.66	380.3
Emu Creek	Emu2	2265		**Dalton St**							
Emu Creek	Emu2	2260	20yr	19		19			1.58		377.46
Emu Creek	Emu2	2260	50yr	33.7		33.7			1.4		378.39
Emu Creek	Emu2	2260	100yr	46.9		46.9			1.69		378.67
Emu Creek	Emu2	2260	200yr	55.6		55.6			1.9		378.78
Emu Creek	Emu2	2260	PMF	193	34.53	149.4	9.07	1.04	3.29	0.58	379.94
Emu Creek	Emu2	2120	20yr	19		19			0.74		377.18
Emu Creek	Emu2	2120	50yr	33.7	0.06	33.29	0.35	0.05	0.84	0.09	378.21
Emu Creek	Emu2	2120	100yr	46.9	1.63	42.52	2.74	0.14	0.98	0.21	378.45
Emu Creek	Emu2	2120	200yr	55.6	2.98	48.51	4.12	0.19	1.09	0.26	378.53
Emu Creek	Emu2	2120	PMF	193	50	102.44	40.55	0.71	1.74	0.75	379.56
Emu Creek	Emu2	2110		**Alexandra St**							

River	Reach	River Station	Profile	Q Total	Q Left	Q Channel	Q Right	Vel Left	Vel Chnl	Vel Right	W.S. Elev
				(m3/s)	(m3/s)	(m3/s)	(m3/s)	(m/s)	(m/s)	(m/s)	(m)
Emu Creek	Emu2	2095	20yr	19		19			0.79		377.04
Emu Creek	Emu2	2095	50yr	33.7		33.7			0.97		377.84
Emu Creek	Emu2	2095	100yr	46.9	0.39	44.52	1.98	0.11	1.07	0.17	378.33
Emu Creek	Emu2	2095	200yr	55.6	1.4	50	4.2	0.17	1.16	0.24	378.45
Emu Creek	Emu2	2095	PMF	193	37.03	102.84	53.13	0.7	1.77	0.76	379.52
Emu Creek	Emu2	2065	20yr	19		19			1.57		376.86
Emu Creek	Emu2	2065	50yr	33.7		33.7			1.76		377.64
Emu Creek	Emu2	2065	100yr	46.9	1.76	40.78	4.36	0.33	1.71	0.38	378.17
Emu Creek	Emu2	2065	200yr	55.6	3.18	44.73	7.69	0.39	1.79	0.48	378.29
Emu Creek	Emu2	2065	PMF	193	44.23	82.93	65.84	1.08	2.42	1.17	379.33
Emu Creek	Emu2	2060		**Mid-Western HWY**							
Emu Creek	Emu2	2055	20yr	19		19			1.66		376.78
Emu Creek	Emu2	2055	50yr	33.7		33.7			2.01		377.38
Emu Creek	Emu2	2055	100yr	46.9		46.9			2.45		377.65
Emu Creek	Emu2	2055	200yr	55.6	0	55.6	0	0.11	2.81	0.06	377.72
Emu Creek	Emu2	2055	PMF	193	41.49	88.33	63.17	1.14	2.67	1.24	379.19
Emu Creek	Emu2	1893	20yr	19	0	19	0	0.05	1.66	0.05	375.1
Emu Creek	Emu2	1893	50yr	33.7	0.48	32.73	0.49	0.52	2.08	0.52	375.67
Emu Creek	Emu2	1893	100yr	46.9	3.98	38.61	4.31	0.58	1.99	0.57	376.15
Emu Creek	Emu2	1893	200yr	55.6	7.49	39.89	8.22	0.68	1.86	0.68	376.42
Emu Creek	Emu2	1893	PMF	193	45.13	97.65	50.23	1.73	3.39	1.74	377.4
Emu Creek	Emu3	1855	20yr	25.5		25.5			1.59		374.99
Emu Creek	Emu3	1855	50yr	44.6	0.03	44.57		0.12	1.8		375.59
Emu Creek	Emu3	1855	100yr	63.3	3.69	59.32	0.29	0.39	1.85	0.25	376.08
Emu Creek	Emu3	1855	200yr	75.6	9.32	64.77	1.51	0.45	1.8	0.35	376.35
Emu Creek	Emu3	1855	PMF	254	96.43	129.67	27.91	1	2.5	0.76	377.4
Emu Creek	Emu3	1840		**Camp St**							

River	Reach	River Station	Profile	Q Total	Q Left	Q Channel	Q Right	Vel Left	Vel Chnl	Vel Right	W.S. Elev
				(m3/s)	(m3/s)	(m3/s)	(m3/s)	(m/s)	(m/s)	(m/s)	(m)
Emu Creek	Emu3	1830	20yr	25.5		25.5			1.77		374.88
Emu Creek	Emu3	1830	50yr	44.6		44.6			2.14		375.33
Emu Creek	Emu3	1830	100yr	63.3		63.3			2.85		375.42
Emu Creek	Emu3	1830	200yr	75.6		75.6			3.3		375.47
Emu Creek	Emu3	1830	PMF	254	79.35	160.69	13.96	1.15	3.58	0.96	376.94
Emu Creek	Emu3	1650	20yr	25.5		25.5			1.28		373.59
Emu Creek	Emu3	1650	50yr	44.6		44.6			1.52		374.13
Emu Creek	Emu3	1650	100yr	63.3	13.63	49.67		0.37	1.39		374.5
Emu Creek	Emu3	1650	200yr	75.6	22.39	53.21		0.44	1.38		374.65
Emu Creek	Emu3	1650	PMF	254	131.13	112.8	10.07	1.01	2.12	0.45	375.47
Emu Creek	Emu3	1645		**Brundah St**							
Emu Creek	Emu3	1640	20yr	25.5		25.5			1.59		373.36
Emu Creek	Emu3	1640	50yr	44.6		44.6			2.11		373.66
Emu Creek	Emu3	1640	100yr	63.3	0.16	63.14		0.19	2.41		373.96
Emu Creek	Emu3	1640	200yr	75.6	2.34	73.26		0.37	2.52		374.12
Emu Creek	Emu3	1640	PMF	254	114.98	136.39	2.63	1.24	2.94	0.44	375.09
Emu Creek	Emu3	1252	20yr	25.5	7.95	13.5	4.04	0.48	1.58	0.48	370.69
Emu Creek	Emu3	1252	50yr	44.6	18.06	18.01	8.52	0.61	1.72	0.55	370.97
Emu Creek	Emu3	1252	100yr	63.3	27.81	22.39	13.1	0.75	1.92	0.63	371.14
Emu Creek	Emu3	1252	200yr	75.6	34.16	25.18	16.26	0.82	2.05	0.68	371.23
Emu Creek	Emu3	1252	PMF	254	125.57	56.57	71.86	1.42	2.92	0.82	372.24
Emu Creek	Emu3	1245		**Bradley S**t							
Emu Creek	Emu3	1240	20yr	25.5	8.8	12.23	4.47	0.52	1.42	0.52	370.7
Emu Creek	Emu3	1240	50yr	44.6	19.42	16.01	9.16	0.66	1.52	0.59	370.98
Emu Creek	Emu3	1240	100yr	63.3	29.6	19.76	13.94	0.79	1.69	0.67	371.15
Emu Creek	Emu3	1240	200yr	75.6	36.31	21.97	17.32	0.86	1.77	0.71	371.25
Emu Creek	Emu3	1240	PMF	254	130.42	48.96	74.62	1.47	2.53	0.85	372.24

River	Reach	River Station	Profile	Q Total	Q Left	Q Channel	Q Right	Vel Left	Vel Chnl	Vel Right	W.S. Elev
				(m3/s)	(m3/s)	(m3/s)	(m3/s)	(m/s)	(m/s)	(m/s)	(m)
Emu Creek	Emu3	804.2	20yr	25.5		25.5			1.08		368.15
Emu Creek	Emu3	804.2	50yr	44.6	0.15	44.45		0.11	1.19		368.52
Emu Creek	Emu3	804.2	100yr	63.3	5.3	58		0.34	1.24		368.73
Emu Creek	Emu3	804.2	200yr	75.6	9.17	66.43		0.43	1.31		368.82
Emu Creek	Emu3	804.2	PMF	254	82.3	171.7		1.02	1.9		369.66
Emu Creek	Emu3	741.8	20yr	25.5		25.5			1.07		367.78
Emu Creek	Emu3	741.8	50yr	44.6		44.6			1.39		368.02
Emu Creek	Emu3	741.8	100yr	63.3	0.64	62.66		0.19	1.61		368.18
Emu Creek	Emu3	741.8	200yr	75.6	3.85	71.75		0.37	1.65		368.28
Emu Creek	Emu3	741.8	PMF	254	54.56	199.44		1.35	3.14		368.71
				Trib Jn							
Emu Creek	Emu4	741.8	20yr	28.6		22.34	6.26		0.92	0.29	367.8
Emu Creek	Emu4	741.8	50yr	48.4		28.01	20.39		0.82	0.37	368.07
Emu Creek	Emu4	741.8	100yr	68.9	1.39	33.95	33.56	0.16	0.8	0.4	368.26
Emu Creek	Emu4	741.8	200yr	82.5	3.57	37.17	41.76	0.22	0.79	0.4	368.36
Emu Creek	Emu4	741.8	PMF	251	30.04	81.51	139.46	0.53	1.09	0.66	368.95
Emu Creek	Emu4	657.7	20yr	28.6		28.6			2.71		366.71
Emu Creek	Emu4	657.7	50yr	48.4		48.4			2.79		367.1
Emu Creek	Emu4	657.7	100yr	68.9		68.9			2.79		367.37
Emu Creek	Emu4	657.7	200yr	82.5		82.5			2.83		367.5
Emu Creek	Emu4	657.7	PMF	251	48.8	178.77	23.42	1.2	2.81	0.82	368.28
Emu Creek	Emu4	285.2	20yr	28.6	25.63	2.04	0.93	0.14	0.3	0.12	364.25
Emu Creek	Emu4	285.2	50yr	48.4	43.9	2.72	1.78	0.14	0.28	0.11	364.62
Emu Creek	Emu4	285.2	100yr	68.9	62.56	3.59	2.75	0.17	0.31	0.12	364.83
Emu Creek	Emu4	285.2	200yr	82.5	74.9	4.19	3.41	0.19	0.34	0.13	364.92
Emu Creek	Emu4	285.2	PMF	251	226.54	11.27	13.2	0.37	0.65	0.25	365.57
Emu Creek	Emu4	8	20yr	28.6		28.6			1.61		363.89
Emu Creek	Emu4	8	50yr	48.4		47.16	1.24		1.66	0.21	364.34
Emu Creek	Emu4	8	100yr	68.9	4.52	50.64	13.74	0.34	1.42	0.38	364.62
Emu Creek	Emu4	8	200yr	82.5	7.23	55.5	19.77	0.41	1.47	0.43	364.7
Emu Creek	Emu4	8	PMF	251	39.39	113.37	98.24	0.96	2.33	0.83	365.13

River	Reach	River Station	Profile	Q Total	Q Left	Q Channel	Q Right	Vel Left	Vel Chnl	Vel Right	W.S. Elev
				(m3/s)	(m3/s)	(m3/s)	(m3/s)	(m/s)	(m/s)	(m/s)	(m)
Emu Creek	Emu4	4		**Holy Camp Rd**							
Emu Creek	Emu4	0	20yr	28.6		28.6			1.71		363.82
Emu Creek	Emu4	0	50yr	48.4		48.4			2.05		364.16
Emu Creek	Emu4	0	100yr	68.9		67.38	1.52		2.4	0.29	364.33
Emu Creek	Emu4	0	200yr	82.5	2.2	69.92	10.38	0.34	2.16	0.49	364.5
Emu Creek	Emu4	0	PMF	251	35.03	129.23	86.75	1.09	2.89	0.98	364.97
Emu Creek	Emu4	-250	20yr	28.6	10.89	16.04	1.67	0.41	0.94	0.26	362.38
Emu Creek	Emu4	-250	50yr	48.4	21.22	22.31	4.87	0.54	1.07	0.34	362.56
Emu Creek	Emu4	-250	100yr	68.9	31.61	28.05	9.24	0.63	1.18	0.4	362.72
Emu Creek	Emu4	-250	200yr	82.5	38.32	31.59	12.6	0.68	1.23	0.43	362.81
Emu Creek	Emu4	-250	PMF	251	112.37	67.4	71.22	1.04	1.67	0.67	363.54

River	Reach	River Station	Profile	Q Total	Q Left	Q Channel	Q Right	Vel Left	Vel Chnl	Vel Right	W.S. Elev
				(m3/s)	(m3/s)	(m3/s)	(m3/s)	(m/s)	(m/s)	(m/s)	(m)
Emu Ck Tributary	Emu Ck Tribut	1548	20yr	2.9		2.9			1.29		383.22
Emu Ck Tributary	Emu Ck Tribut	1548	50yr	5.6		5.6			1.08		383.4
Emu Ck Tributary	Emu Ck Tribut	1548	100yr	6.8		6.8			0.7		383.61
Emu Ck Tributary	Emu Ck Tribut	1548	200yr	8.4		8.4			0.48		383.89
Emu Ck Tributary	Emu Ck Tribut	1548	PMF	34		34			0.71		384.86
Emu Ck Tributary	Emu Ck Tribut	1544	20yr	2.9	0	2.9	0	0.04	1.06	0.04	382.91
Emu Ck Tributary	Emu Ck Tribut	1544	50yr	5.6	0.86	3.59	1.14	0.27	0.94	0.36	383.4
Emu Ck Tributary	Emu Ck Tribut	1544	100yr	6.8	1.66	3.42	1.72	0.27	0.8	0.35	383.61
Emu Ck Tributary	Emu Ck Tribut	1544	200yr	8.4	2.58	3.43	2.39	0.19	0.71	0.3	383.88
Emu Ck Tributary	Emu Ck Tribut	1544	PMF	34	21.03	4.43	8.54	0.34	0.63	0.28	384.87
Emu Ck Tributary	Emu Ck Tribut	1540		**Mid-Western HWY**							
Emu Ck Tributary	Emu Ck Tribut	1537	20yr	2.9		2.9			1.1		382.87
Emu Ck Tributary	Emu Ck Tribut	1537	50yr	5.6	0.37	4.54	0.68	0.3	1.34	0.4	383.21
Emu Ck Tributary	Emu Ck Tribut	1537	100yr	6.8	0.7	5.01	1.1	0.36	1.4	0.47	383.29
Emu Ck Tributary	Emu Ck Tribut	1537	200yr	8.4	1.21	5.54	1.65	0.41	1.47	0.55	383.38
Emu Ck Tributary	Emu Ck Tribut	1537	PMF	34	11.23	13.21	9.56	0.73	2.67	1.14	383.92
Emu Ck Tributary	Emu Ck Tribut	1182.5	20yr	2.9		2.9			0.94		377.55
Emu Ck Tributary	Emu Ck Tribut	1182.5	50yr	5.6		5.6			1.1		377.6
Emu Ck Tributary	Emu Ck Tribut	1182.5	100yr	6.8		6.8			1.14		377.62
Emu Ck Tributary	Emu Ck Tribut	1182.5	200yr	8.4		8.4			1.2		377.64
Emu Ck Tributary	Emu Ck Tribut	1182.5	PMF	34	22.99	11.01		0.79	0.79		377.76
Emu Ck Tributary	Emu Ck Tribut	940	20yr	6.1	2.05	2.05	2	0.12	0.31	0.12	374.06
Emu Ck Tributary	Emu Ck Tribut	940	50yr	12.9	4.85	3.54	4.5	0.21	0.48	0.19	374.22
Emu Ck Tributary	Emu Ck Tribut	940	100yr	14.9	5.71	3.9	5.29	0.23	0.51	0.2	374.26
Emu Ck Tributary	Emu Ck Tribut	940	200yr	18.5	7.14	4.62	6.74	0.27	0.58	0.24	374.3
Emu Ck Tributary	Emu Ck Tribut	940	PMF	70	27.54	12.7	29.76	0.67	1.27	0.62	374.65
Emu Ck Tributary	Emu Ck Tribut	930		**Manganese Rd**							

River	Reach	River Station	Profile	Q Total	Q Left	Q Channel	Q Right	Vel Left	Vel Chnl	Vel Right	W.S. Elev
				(m3/s)	(m3/s)	(m3/s)	(m3/s)	(m/s)	(m/s)	(m/s)	(m)
Emu Ck Tributary	Emu Ck Tribut	926	20yr	6.2	0.71	5.24	0.26	0.66	1.77	0.37	373.47
Emu Ck Tributary	Emu Ck Tribut	926	50yr	12.9	1.94	8.42	2.54	0.59	2	0.62	373.68
Emu Ck Tributary	Emu Ck Tribut	926	100yr	15.3	2.61	9.2	3.49	0.6	2.04	0.66	373.73
Emu Ck Tributary	Emu Ck Tribut	926	200yr	18.5	3.54	10.29	4.67	0.63	2.15	0.72	373.78
Emu Ck Tributary	Emu Ck Tribut	926	PMF	70	24.96	21.45	23.59	1.28	3.11	1.19	374.13
Emu Ck Tributary	Emu Ck Tribut	356	20yr	6.2	1.55	3.54	1.11	0.13	0.29	0.13	368.65
Emu Ck Tributary	Emu Ck Tribut	356	50yr	12.9	3.8	6.38	2.72	0.18	0.4	0.18	368.87
Emu Ck Tributary	Emu Ck Tribut	356	100yr	15.3	4.5	7.58	3.22	0.22	0.47	0.22	368.87
Emu Ck Tributary	Emu Ck Tribut	356	200yr	18.5	5.59	8.92	4	0.24	0.53	0.24	368.92
Emu Ck Tributary	Emu Ck Tribut	356	PMF	70	25.93	25.52	18.55	0.45	0.95	0.45	369.46
Emu Ck Tributary	Emu Ck Tribut	13.5	20yr	6.2		6.2			0.93		368.01
Emu Ck Tributary	Emu Ck Tribut	13.5	50yr	12.9		12.9			1.14		368.06
Emu Ck Tributary	Emu Ck Tribut	13.5	100yr	15.3		15.3			0.47		368.27
Emu Ck Tributary	Emu Ck Tribut	13.5	200yr	18.5		18.5			0.41		368.38
Emu Ck Tributary	Emu Ck Tribut	13.5	PMF	70		70			0.48		368.98
Emu Ck Tributary	Emu Ck Tribut	0	20yr	6.2		6.2			0.01		367.83
Emu Ck Tributary	Emu Ck Tribut	0	50yr	12.9		12.9			0.03		368.09
Emu Ck Tributary	Emu Ck Tribut	0	100yr	15.3		15.3			0.03		368.28
Emu Ck Tributary	Emu Ck Tribut	0	200yr	18.5		18.5			0.04		368.38
Emu Ck Tributary	Emu Ck Tribut	0	PMF	70		70			0.11		368.99

River	Reach	River Station	Profile	Q Total	Q Left	Q Channel	Q Right	Vel Left	Vel Chnl	Vel Right	W.S. Elev
				(m3/s)	(m3/s)	(m3/s)	(m3/s)	(m/s)	(m/s)	(m/s)	(m)
Gooloogong Tributary	Gooloogong Trib	1018.4	20yr	6		6			1.1		395.71
Gooloogong Tributary	Gooloogong Trib	1018.4	50yr	11.8		11.8			1.14		395.97
Gooloogong Tributary	Gooloogong Trib	1018.4	100yr	14.2	0	14.19	0	0.11	1.17	0.11	396.05
Gooloogong Tributary	Gooloogong Trib	1018.4	200yr	17.5	0.01	17.49	0.01	0.16	1.41	0.16	396.06
Gooloogong Tributary	Gooloogong Trib	1018.4	PMF	70	5.26	60.19	4.55	0.86	2.02	0.7	396.85
Gooloogong Tributary	Gooloogong Trib	966	20yr	6	0	5.99	0	0.17	1.86	0.17	394.56
Gooloogong Tributary	Gooloogong Trib	966	50yr	11.8	0.61	10.82	0.37	0.63	2.42	0.63	394.87
Gooloogong Tributary	Gooloogong Trib	966	100yr	14.2	1.03	12.54	0.63	0.74	2.63	0.74	394.94
Gooloogong Tributary	Gooloogong Trib	966	200yr	17.5	2.92	12.78	1.8	0.73	2.13	0.73	395.25
Gooloogong Tributary	Gooloogong Trib	966	PMF	70	24.81	30.33	14.86	1.45	3.26	1.37	396.07
Gooloogong Tributary	Gooloogong Trib	540	20yr	6	0.02	5.97	0.01	0.12	1.28	0.12	389.27
Gooloogong Tributary	Gooloogong Trib	540	50yr	11.8	1.96	8.9	0.94	0.38	1.48	0.38	389.61
Gooloogong Tributary	Gooloogong Trib	540	100yr	14.2	3.15	9.54	1.51	0.42	1.5	0.42	389.69
Gooloogong Tributary	Gooloogong Trib	540	200yr	17.5	3.45	12.39	1.66	0.54	1.99	0.54	389.65
Gooloogong Tributary	Gooloogong Trib	540	PMF	70	33.81	20.02	16.17	1.02	2.32	1.02	390.26
Gooloogong Tributary	Gooloogong Trib	323.5	20yr	6		6			2.52		385.4
Gooloogong Tributary	Gooloogong Trib	323.5	50yr	11.8		11.8			2.95		385.8
Gooloogong Tributary	Gooloogong Trib	323.5	100yr	14.2		14.2			3.09		385.93
Gooloogong Tributary	Gooloogong Trib	323.5	200yr	17.5	2.57	14.71	0.22	0.5	2.23	0.38	386.33
Gooloogong Tributary	Gooloogong Trib	323.5	PMF	70	35.54	28.43	6.04	1.09	3.08	0.93	386.86
Gooloogong Tributary	Gooloogong Trib	120	20yr	6		6			0.88		383.17
Gooloogong Tributary	Gooloogong Trib	120	50yr	11.8	0.12	10.23	1.45	0.12	0.89	0.15	383.61
Gooloogong Tributary	Gooloogong Trib	120	100yr	14.2	0.24	11.47	2.49	0.15	0.94	0.18	383.67
Gooloogong Tributary	Gooloogong Trib	120	200yr	17.5	0.44	12.9	4.16	0.18	1	0.2	383.74
Gooloogong Tributary	Gooloogong Trib	120	PMF	70	4.71	30.24	35.05	0.43	1.78	0.5	384.11

River	Reach	River Station	Profile	Q Total	Q Left	Q Channel	Q Right	Vel Left	Vel Chnl	Vel Right	W.S. Elev
				(m3/s)	(m3/s)	(m3/s)	(m3/s)	(m/s)	(m/s)	(m/s)	(m)
Gooloogong Tributary	Gooloogong Trib	115		**Stock Route**							
Gooloogong Tributary	Gooloogong Trib	111	20yr	6		6			1.94		382.76
Gooloogong Tributary	Gooloogong Trib	111	50yr	11.8		11.8			2.34		382.99
Gooloogong Tributary	Gooloogong Trib	111	100yr	14.2		14.2			2.46		383.06
Gooloogong Tributary	Gooloogong Trib	111	200yr	17.5		17.5			2.59		383.16
Gooloogong Tributary	Gooloogong Trib	111	PMF	70	4.66	30.68	34.66	0.43	1.82	0.51	384.1
Gooloogong Tributary	Gooloogong Trib	25	20yr	6.6		6.6			0.81		381.08
Gooloogong Tributary	Gooloogong Trib	25	50yr	11.8		11.8			0.71		381.62
Gooloogong Tributary	Gooloogong Trib	25	100yr	16.5		16.5			0.73		381.94
Gooloogong Tributary	Gooloogong Trib	25	200yr	19.5		19.5			0.73		382.13
Gooloogong Tributary	Gooloogong Trib	25	PMF	72		69.42	2.58		0.88	0.3	383.98

River	Reach	River Station	Profile	Q Total	Q Left	Q Channel	Q Right	Vel Left	Vel Chnl	Vel Right	W.S. Elev
				(m3/s)	(m3/s)	(m3/s)	(m3/s)	(m/s)	(m/s)	(m/s)	(m)
O'Brien Tributary	O'Brien 1	1651	20yr	2.1	0.18	1.7	0.21	0.03	0.1	0.03	404.85
O'Brien Tributary	O'Brien 1	1651	50yr	4	0.41	3.12	0.47	0.06	0.17	0.06	404.92
O'Brien Tributary	O'Brien 1	1651	100yr	4.9	0.53	3.77	0.6	0.06	0.19	0.07	404.95
O'Brien Tributary	O'Brien 1	1651	200yr	6	0.68	4.55	0.77	0.08	0.23	0.08	404.97
O'Brien Tributary	O'Brien 1	1651	PMF	25	4.21	16.37	4.43	0.23	0.66	0.25	405.22
O'Brien Tributary	O'Brien 1	1647		**Brickfield Rd**							
O'Brien Tributary	O'Brien 1	1643	20yr	2.1		2.1			1.26		403.98
O'Brien Tributary	O'Brien 1	1643	50yr	4		4			1.45		404.07
O'Brien Tributary	O'Brien 1	1643	100yr	4.9		4.9			1.51		404.11
O'Brien Tributary	O'Brien 1	1643	200yr	6		6			1.58		404.15
O'Brien Tributary	O'Brien 1	1643	PMF	25	0.6	23.74	0.66	0.56	2.11	0.56	404.54
O'Brien Tributary	O'Brien 1	1335	20yr	2.1		2.1			0.39		396.59
O'Brien Tributary	O'Brien 1	1335	50yr	4		4			0.44		396.7
O'Brien Tributary	O'Brien 1	1335	100yr	4.9		4.9			0.46		396.74
O'Brien Tributary	O'Brien 1	1335	200yr	6		6			0.47		396.78
O'Brien Tributary	O'Brien 1	1335	PMF	25		25			0.57		397.24
O'Brien Tributary	O'Brien 1	1085	20yr	2.1		2.1			0.47		394.9
O'Brien Tributary	O'Brien 1	1085	50yr	4		4			0.57		394.98
O'Brien Tributary	O'Brien 1	1085	100yr	4.9		4.9			0.61		395.01
O'Brien Tributary	O'Brien 1	1085	200yr	6		6			0.65		395.04
O'Brien Tributary	O'Brien 1	1085	PMF	25		25			1.57		395.17
				Warraderry St							
O'Brien Tributary	O'Brien 1	811	20yr	3.5		3.5			0.85		389.91
O'Brien Tributary	O'Brien 1	811	50yr	6.6		6.6			0.98		389.95
O'Brien Tributary	O'Brien 1	811	100yr	8.3		8.3			1.03		389.97
O'Brien Tributary	O'Brien 1	811	200yr	10		10			1.07		389.99
O'Brien Tributary	O'Brien 1	811	PMF	45		45			1.31		390.21

River	Reach	River Station	Profile	Q Total	Q Left	Q Channel	Q Right	Vel Left	Vel Chnl	Vel Right	W.S. Elev
				(m3/s)	(m3/s)	(m3/s)	(m3/s)	(m/s)	(m/s)	(m/s)	(m)
				Camp St							
O'Brien Tributary	O'Brien 1	668	20yr	3.5		3.5			0.43		387.01
O'Brien Tributary	O'Brien 1	668	50yr	6.6		6.6			0.56		387.08
O'Brien Tributary	O'Brien 1	668	100yr	8.3		8.3			0.62		387.1
O'Brien Tributary	O'Brien 1	668	200yr	10		10			0.65		387.13
O'Brien Tributary	O'Brien 1	668	PMF	45		45			1.73		387.26
O'Brien Tributary	O'Brien 1	486	20yr	6.5		6.5			0.98		383.55
O'Brien Tributary	O'Brien 1	486	50yr	10.4		10.4			1.11		383.59
O'Brien Tributary	O'Brien 1	486	100yr	12		12			1.15		383.6
O'Brien Tributary	O'Brien 1	486	200yr	14.6		14.6			1.22		383.62
O'Brien Tributary	O'Brien 1	486	PMF	59.8	0.05	59.75		0.19	1.07		384.02
				Short St							
O'Brien Tributary	O'Brien 1	481	20yr	6.5	0.97	4.17	1.36	0.85	3.07	0.85	382.98
O'Brien Tributary	O'Brien 1	481	50yr	10.4	2.38	4.68	3.35	0.84	2.69	0.76	383.17
O'Brien Tributary	O'Brien 1	481	100yr	12	2.98	4.6	4.42	0.78	2.42	0.71	383.25
O'Brien Tributary	O'Brien 1	481	200yr	14.6	3.86	4.72	6.02	0.75	2.27	0.69	383.34
O'Brien Tributary	O'Brien 1	481	PMF	59.8	17.96	7.95	33.89	0.77	2.38	0.78	383.97
O'Brien Tributary	O'Brien 1	402	20yr	6.5	2.6	1.46	2.44	0.19	0.57	0.21	382.92
O'Brien Tributary	O'Brien 1	402	50yr	10.4	4.24	2.13	4.03	0.24	0.79	0.29	383
O'Brien Tributary	O'Brien 1	402	100yr	12	4.95	2.37	4.68	0.26	0.86	0.32	383.03
O'Brien Tributary	O'Brien 1	402	200yr	14.6	6.14	2.74	5.72	0.29	0.96	0.36	383.07
O'Brien Tributary	O'Brien 1	402	PMF	59.8	31.81	5.88	22.11	0.65	1.5	0.62	383.61
				Nash St							
O'Brien Tributary	O'Brien 1	398	20yr	6.5		6.5			0.57		382.9
O'Brien Tributary	O'Brien 1	398	50yr	10.4		10.4			0.61		382.98
O'Brien Tributary	O'Brien 1	398	100yr	12		12			0.62		383.01
O'Brien Tributary	O'Brien 1	398	200yr	14.6		14.6			0.64		383.06
O'Brien Tributary	O'Brien 1	398	PMF	59.8		59.76	0.04		0.76	0.08	383.6
O'Brien Tributary	O'Brien 1	293	20yr	6.5	1.39	4.97	0.15	0.68	1.04	0.36	382.37
O'Brien Tributary	O'Brien 1	293	50yr	10.4	2.23	7.78	0.39	0.84	1.27	0.47	382.46
O'Brien Tributary	O'Brien 1	293	100yr	12	2.57	8.91	0.52	0.88	1.34	0.5	382.49
O'Brien Tributary	O'Brien 1	293	200yr	14.6	3.12	10.74	0.74	0.97	1.47	0.56	382.53
O'Brien Tributary	O'Brien 1	293	PMF	59.8	11.76	40.26	7.79	1.66	2.58	1.36	383.09

River	Reach	River Station	Profile	Q Total	Q Left	Q Channel	Q Right	Vel Left	Vel Chnl	Vel Right	W.S. Elev
				(m3/s)	(m3/s)	(m3/s)	(m3/s)	(m/s)	(m/s)	(m/s)	(m)
O'Brien Tributary	O'Brien 1	183	20yr	6.5	1.44	4.96	0.1	1.01	1.52	0.46	381.14
O'Brien Tributary	O'Brien 1	183	50yr	10.4	2.31	7.75	0.34	1.18	1.75	0.6	381.22
O'Brien Tributary	O'Brien 1	183	100yr	12	2.65	8.88	0.47	1.25	1.85	0.65	381.24
O'Brien Tributary	O'Brien 1	183	200yr	14.6	3.2	10.65	0.75	1.3	1.93	0.71	381.29
O'Brien Tributary	O'Brien 1	183	PMF	59.8	11.89	39.56	8.35	2.05	3.13	1.72	381.77
O'Brien Tributary	O'Brien 1	113	20yr	6.5		5.39	1.11		0.64	0.31	380.65
O'Brien Tributary	O'Brien 1	113	50yr	10.4		8.31	2.09		0.77	0.36	380.76
O'Brien Tributary	O'Brien 1	113	100yr	12		9.46	2.54		0.81	0.38	380.8
O'Brien Tributary	O'Brien 1	113	200yr	14.6		11.29	3.31		0.86	0.41	380.86
O'Brien Tributary	O'Brien 1	113	PMF	59.8		36.26	23.54		1.24	0.7	381.56
O'Brien Tributary	O'Brien 1	58	20yr	6.5	1.27	4.45	0.78	0.6	0.91	0.48	380.48
O'Brien Tributary	O'Brien 1	58	50yr	10.4	2.03	6.93	1.45	0.73	1.09	0.61	380.57
O'Brien Tributary	O'Brien 1	58	100yr	12	2.33	7.93	1.74	0.77	1.15	0.65	380.61
O'Brien Tributary	O'Brien 1	58	200yr	14.6	2.83	9.55	2.22	0.83	1.25	0.72	380.66
O'Brien Tributary	O'Brien 1	58	PMF	59.8	11.11	37.71	10.98	1.48	2.28	1.41	381.25
O'Brien Tributary	O'Brien 1	1	20yr	6.5	1.13	4.78	0.58	0.97	1.6	0.8	379.93
O'Brien Tributary	O'Brien 1	1	50yr	10.4	1.96	7.28	1.16	1.13	1.76	0.94	380.01
O'Brien Tributary	O'Brien 1	1	100yr	12	2.33	8.27	1.4	1.22	1.84	0.99	380.04
O'Brien Tributary	O'Brien 1	1	200yr	14.6	2.86	9.97	1.77	1.3	1.95	1.03	380.08
O'Brien Tributary	O'Brien 1	1	PMF	59.8	11.32	38.03	10.45	2.06	3.13	1.91	380.55

River	Reach	River Station	Profile	Q Total	Q Left	Q Channel	Q Right	Vel Left	Vel Chnl	Vel Right	W.S. Elev
				(m3/s)	(m3/s)	(m3/s)	(m3/s)	(m/s)	(m/s)	(m/s)	(m)
Company Dam Overflow	Company Dam OF	854	20yr	6.7		6.7			0.71		385.05
Company Dam Overflow	Company Dam OF	854	50yr	12.5		12.5			0.83		385.34
Company Dam Overflow	Company Dam OF	854	100yr	17.7	0	17.7		0.08	0.93		385.51
Company Dam Overflow	Company Dam OF	854	200yr	21	0.01	20.99	0	0.12	1.05	0.05	385.56
Company Dam Overflow	Company Dam OF	854	PMF	70	2.51	62.31	5.18	0.5	1.63	0.49	386.35
Company Dam Overflow	Company Dam OF	681	20yr	6.7	0.72	5.98		0.74	1.73		383.32
Company Dam Overflow	Company Dam OF	681	50yr	12.5	2.03	10.47		1.18	2.26		383.47
Company Dam Overflow	Company Dam OF	681	100yr	17.7	3.38	14.32		1.45	2.52		383.6
Company Dam Overflow	Company Dam OF	681	200yr	21	3.85	14.94	2.2	1.37	2.28	0.71	383.69
Company Dam Overflow	Company Dam OF	681	PMF	70	11.38	38.8	19.82	2.13	3.5	1.78	384.2
Company Dam Overflow	Company Dam OF	630	20yr	6.7		6.7			0.7		383.01
Company Dam Overflow	Company Dam OF	630	50yr	12.5	11.64	0.86	0	0.05	0.06	0.01	383.26
Company Dam Overflow	Company Dam OF	630	100yr	17.7	16.48	1.22	0	0.06	0.09	0.01	383.25
Company Dam Overflow	Company Dam OF	630	200yr	21	19.55	1.45	0	0.08	0.11	0.01	383.25
Company Dam Overflow	Company Dam OF	630	PMF	70	65.17	4.81	0.02	0.25	0.35	0.05	383.26
Company Dam Overflow	Company Dam OF	625		**North St**							
Company Dam Overflow	Company Dam OF	620	20yr	6.7		6.7			0.81		382.92
Company Dam Overflow	Company Dam OF	620	50yr	12.5		12.49	0.01		0.97	0.1	383.21
Company Dam Overflow	Company Dam OF	620	100yr	17.7	16.48	1.22	0	0.06	0.09	0.01	383.25
Company Dam Overflow	Company Dam OF	620	200yr	21	19.55	1.45	0	0.08	0.11	0.01	383.25
Company Dam Overflow	Company Dam OF	620	PMF	70	65.16	4.82	0.02	0.26	0.36	0.05	383.25
Company Dam Overflow	Company Dam OF	549	20yr	6.7		6.7			0.88		382.21
Company Dam Overflow	Company Dam OF	549	50yr	12.5	0	12.5		0.17	1.46		382.23
Company Dam Overflow	Company Dam OF	549	100yr	17.7	0.02	17.68		0.35	1.63		382.29
Company Dam Overflow	Company Dam OF	549	200yr	21	0.06	20.94	0	0.43	1.7	0.15	382.32
Company Dam Overflow	Company Dam OF	549	PMF	70	1.29	68.3	0.41	1.3	3.23	0.92	382.53

River	Reach	River Station	Profile	Q Total	Q Left	Q Channel	Q Right	Vel Left	Vel Chnl	Vel Right	W.S. Elev
				(m3/s)	(m3/s)	(m3/s)	(m3/s)	(m/s)	(m/s)	(m/s)	(m)
Company Dam Overflow	Company Dam OF	300	20yr	6.7		6.7			1.03		379.24
Company Dam Overflow	Company Dam OF	300	50yr	12.5		12.5	0		0.55	0.04	379.91
Company Dam Overflow	Company Dam OF	300	100yr	17.7		17.62	0.08		0.53	0.13	380.08
Company Dam Overflow	Company Dam OF	300	200yr	21		20.83	0.17		0.56	0.15	380.14
Company Dam Overflow	Company Dam OF	300	PMF	70		66.93	3.07		1.06	0.46	380.55
Company Dam Overflow	Company Dam OF	294		**Melyra St**							
Company Dam Overflow	Company Dam OF	290	20yr	6.7		6.7			1.35		379.07
Company Dam Overflow	Company Dam OF	290	50yr	12.5		12.5			1.08		379.63
Company Dam Overflow	Company Dam OF	290	100yr	17.7		17.7			0.83		379.88
Company Dam Overflow	Company Dam OF	290	200yr	21		20.99	0.01		0.8	0.13	379.97
Company Dam Overflow	Company Dam OF	290	PMF	70		67.92	2.08		1.25	0.46	380.41
Company Dam Overflow	Company Dam OF	220	20yr	6.7	5.92	0.78	0	0.24	0.33	0.01	378.72
Company Dam Overflow	Company Dam OF	220	50yr	12.5	11.05	1.45	0	0.45	0.61	0.02	378.72
Company Dam Overflow	Company Dam OF	220	100yr	17.7	15.65	2.05	0	0.63	0.86	0.03	378.72
Company Dam Overflow	Company Dam OF	220	200yr	21	18.57	2.43	0	0.75	1.01	0.05	378.72
Company Dam Overflow	Company Dam OF	220	PMF	70	60.27	7.55	2.18	1.19	1.54	0.63	379.14
Company Dam Overflow	Company Dam OF	150	20yr	6.7	2.73	3.09	0.88	0.9	4.17	0.93	377.96
Company Dam Overflow	Company Dam OF	150	50yr	12.5	8.18	1.79	2.53	0.29	0.86	0.22	378.29
Company Dam Overflow	Company Dam OF	150	100yr	17.7	11.42	2.3	3.98	0.35	1	0.28	378.35
Company Dam Overflow	Company Dam OF	150	200yr	21	13.49	2.66	4.85	0.39	1.11	0.32	378.37
Company Dam Overflow	Company Dam OF	150	PMF	70	42.88	6.74	20.38	0.66	1.71	0.59	378.76
Company Dam Overflow	Company Dam OF	149.5	20yr	6.7	0.81	5.66	0.23	0.15	1.02	0.15	378
Company Dam Overflow	Company Dam OF	149.5	50yr	12.5	5.85	4.92	1.74	0.22	0.68	0.16	378.28
Company Dam Overflow	Company Dam OF	149.5	100yr	17.7	8.7	6.08	2.92	0.27	0.8	0.21	378.34
Company Dam Overflow	Company Dam OF	149.5	200yr	21	10.45	6.94	3.62	0.31	0.9	0.25	378.36
Company Dam Overflow	Company Dam OF	149.5	PMF	70	38.5	13.52	17.97	0.6	1.35	0.54	378.75

River	Reach	River Station	Profile	Q Total	Q Left	Q Channel	Q Right	Vel Left	Vel Chnl	Vel Right	W.S. Elev
				(m3/s)	(m3/s)	(m3/s)	(m3/s)	(m/s)	(m/s)	(m/s)	(m)
Company Dam Overflow	Company Dam OF	140		**Mid-Western HWY**							
Company Dam Overflow	Company Dam OF	135	20yr	6.7		6.7			1.52		377.82
Company Dam Overflow	Company Dam OF	135	50yr	12.5	2.84	8.9	0.76	0.28	1.51	0.26	378.06
Company Dam Overflow	Company Dam OF	135	100yr	17.7	6.6	9.36	1.74	0.37	1.44	0.3	378.16
Company Dam Overflow	Company Dam OF	135	200yr	21	8.22	10.57	2.2	0.43	1.6	0.34	378.18
Company Dam Overflow	Company Dam OF	135	PMF	72	39.56	14.05	18.39	0.63	1.41	0.56	378.74
Company Dam Overflow	Company Dam OF	24	20yr	6.7	0	6.7	0	0.07	2.52	0.07	375.27
Company Dam Overflow	Company Dam OF	24	50yr	12.5	0.15	12.21	0.15	0.95	3.4	0.95	375.66
Company Dam Overflow	Company Dam OF	24	100yr	17.7	0.79	16.25	0.66	1.37	3.63	1.14	376.03
Company Dam Overflow	Company Dam OF	24	200yr	21	1.62	16.34	3.04	1.37	2.98	0.88	376.45
Company Dam Overflow	Company Dam OF	24	PMF	72	4.82	30.53	36.65	1.82	3.86	2.24	377.45

River	Reach	River Station	Profile	Q Total	Q Left	Q Channel	Q Right	Vel Left	Vel Chnl	Vel Right	W.S. Elev
				(m3/s)	(m3/s)	(m3/s)	(m3/s)	(m/s)	(m/s)	(m/s)	(m)
Southern Tributary	Southern Trib	2270	20yr	0.9		0.9			0.33		385.04
Southern Tributary	Southern Trib	2270	50yr	1.6		1.6			0.33		385.11
Southern Tributary	Southern Trib	2270	100yr	2.2		2.2			0.34		385.15
Southern Tributary	Southern Trib	2270	200yr	2.6		2.6			0.35		385.17
Southern Tributary	Southern Trib	2270	PMF	12.4		12.4			0.58		385.43
				Walshs Lne							
Southern Tributary	Southern Trib	2024	20yr	0.9		0.9			0.6		382.67
Southern Tributary	Southern Trib	2024	50yr	1.6		1.6			0.82		382.76
Southern Tributary	Southern Trib	2024	100yr	2.2		2.2			0.93		382.82
Southern Tributary	Southern Trib	2024	200yr	2.6		2.6			0.99		382.86
Southern Tributary	Southern Trib	2024	PMF	12.4		12.4			1.13		383.64
Southern Tributary	Southern Trib	1984	20yr	0.9		0.9			1.35		381.83
Southern Tributary	Southern Trib	1984	50yr	1.6		1.6			1.08		382.02
Southern Tributary	Southern Trib	1984	100yr	2.2		2.2			1.04		382.13
Southern Tributary	Southern Trib	1984	200yr	2.6		2.6			1.02		382.2
Southern Tributary	Southern Trib	1984	PMF	12.4		12.4			0.6		383.55
Southern Tributary	Southern Trib	1974		**H Law Way**							
Southern Tributary	Southern Trib	1964	20yr	0.9		0.9			0.83		381.71
Southern Tributary	Southern Trib	1964	50yr	1.6		1.6			1.11		381.79
Southern Tributary	Southern Trib	1964	100yr	2.2		2.2			1.18		381.87
Southern Tributary	Southern Trib	1964	200yr	2.6		2.6			1.21		381.92
Southern Tributary	Southern Trib	1964	PMF	12.4		12.4			1.43		382.61
Southern Tributary	Southern Trib	1924	20yr	0.9		0.9			0.88		381.05
Southern Tributary	Southern Trib	1924	50yr	1.6		1.6			0.8		381.24
Southern Tributary	Southern Trib	1924	100yr	2.2		2.2			0.87		381.32
Southern Tributary	Southern Trib	1924	200yr	2.6		2.6			0.91		381.37
Southern Tributary	Southern Trib	1924	PMF	12.4		12.4			2.29		381.67

River	Reach	River Station	Profile	Q Total	Q Left	Q Channel	Q Right	Vel Left	Vel Chnl	Vel Right	W.S. Elev
				(m3/s)	(m3/s)	(m3/s)	(m3/s)	(m/s)	(m/s)	(m/s)	(m)
Southern Tributary	Southern Trib	1824	20yr	0.9		0.9			0.65		378.69
Southern Tributary	Southern Trib	1824	50yr	1.6		1.6			1.19		378.68
Southern Tributary	Southern Trib	1824	100yr	2.2		2.2			1.29		378.72
Southern Tributary	Southern Trib	1824	200yr	2.6		2.6			1.35		378.74
Southern Tributary	Southern Trib	1824	PMF	12.4		12.4			0.47		379.86
Southern Tributary	Southern Trib	1784	20yr	0.9		0.9			0.5		378.07
Southern Tributary	Southern Trib	1784	50yr	1.6		1.6			0.42		378.24
Southern Tributary	Southern Trib	1784	100yr	2.2		2.2			0.39		378.37
Southern Tributary	Southern Trib	1784	200yr	2.6		2.6			0.37		378.44
Southern Tributary	Southern Trib	1784	PMF	15	0.3	14.41	0.29	0.08	0.29	0.09	379.84
Southern Tributary	Southern Trib	1774		**Holy Camp Rd**							
Southern Tributary	Southern Trib	1764	20yr	0.9		0.9			0.24		377.93
Southern Tributary	Southern Trib	1764	50yr	1.6		1.6			0.25		378.11
Southern Tributary	Southern Trib	1764	100yr	2.2		2.2			0.25		378.23
Southern Tributary	Southern Trib	1764	200yr	2.6		2.6			0.26		378.3
Southern Tributary	Southern Trib	1764	PMF	15	0	15		0.04	0.47		379.06
Southern Tributary	Southern Trib	1724	20yr	0.9		0.9			0.12		377.92
Southern Tributary	Southern Trib	1724	50yr	1.6		1.6			0.14		378.1
Southern Tributary	Southern Trib	1724	100yr	2.2		2.2			0.16		378.22
Southern Tributary	Southern Trib	1724	200yr	2.6		2.6			0.17		378.28
Southern Tributary	Southern Trib	1724	PMF	15	0.08	14.89	0.03	0.08	0.37	0.05	379.03
Southern Tributary	Southern Trib	1217	20yr	7.9		7.9			0.97		372.98
Southern Tributary	Southern Trib	1217	50yr	14.1		14.1			1.16		373.02
Southern Tributary	Southern Trib	1217	100yr	19.6		19.6			1.28		373.06
Southern Tributary	Southern Trib	1217	200yr	23.1		23.1			1.35		373.08
Southern Tributary	Southern Trib	1217	PMF	95.6		95.6			2.04		373.36

River	Reach	River Station	Profile	Q Total	Q Left	Q Channel	Q Right	Vel Left	Vel Chnl	Vel Right	W.S. Elev
				(m3/s)	(m3/s)	(m3/s)	(m3/s)	(m/s)	(m/s)	(m/s)	(m)
Southern Tributary	Southern Trib	970	20yr	7.9		6.57	1.33		0.33	0.15	370.96
Southern Tributary	Southern Trib	970	50yr	14.1		11.11	2.99		0.39	0.21	371.07
Southern Tributary	Southern Trib	970	100yr	19.6		15.13	4.47		0.44	0.25	371.14
Southern Tributary	Southern Trib	970	200yr	23.1		17.65	5.45		0.46	0.27	371.18
Southern Tributary	Southern Trib	970	PMF	95.6		70.7	24.9		0.81	0.55	371.65
Southern Tributary	Southern Trib	930	20yr	7.9		6.77	1.13		0.16	0.07	370.95
Southern Tributary	Southern Trib	930	50yr	14.1		11.72	2.38		0.23	0.12	371.05
Southern Tributary	Southern Trib	930	100yr	19.6		16.06	3.54		0.28	0.15	371.11
Southern Tributary	Southern Trib	930	200yr	23.1		18.77	4.33		0.3	0.16	371.16
Southern Tributary	Southern Trib	930	PMF	95.6		75.18	20.42		0.67	0.42	371.58
Southern Tributary	Southern Trib	920		**Berry's Rd**							
Southern Tributary	Southern Trib	910	20yr	7.9		7.86	0.04		0.69	0.16	370.35
Southern Tributary	Southern Trib	910	50yr	14.1		13.65	0.45		0.62	0.21	370.49
Southern Tributary	Southern Trib	910	100yr	19.6		18.72	0.88		0.7	0.25	370.55
Southern Tributary	Southern Trib	910	200yr	23.1		21.9	1.2		0.75	0.27	370.58
Southern Tributary	Southern Trib	910	PMF	95.6		81.98	13.62		1.2	0.58	370.99
Southern Tributary	Southern Trib	870	20yr	7.9		7.85	0.05		0.56	0.15	369.98
Southern Tributary	Southern Trib	870	50yr	14.1		14.06	0.04		1.25	0.29	369.94
Southern Tributary	Southern Trib	870	100yr	19.6		19.47	0.13		1.38	0.38	369.98
Southern Tributary	Southern Trib	870	200yr	23.1		22.89	0.21		1.44	0.42	370.01
Southern Tributary	Southern Trib	870	PMF	95.6		90.74	4.86		2.11	0.83	370.33
Southern Tributary	Southern Trib	714	20yr	7.9		7.9			1.02		367.79
Southern Tributary	Southern Trib	714	50yr	14.1		14.1			0.18		368.36
Southern Tributary	Southern Trib	714	100yr	19.6		19.6			0.19		368.5
Southern Tributary	Southern Trib	714	200yr	23.1		23.1			0.21		368.55
Southern Tributary	Southern Trib	714	PMF	95.6		95.6			0.52		368.94

River	Reach	River Station	Profile	Q Total	Q Left	Q Channel	Q Right	Vel Left	Vel Chnl	Vel Right	W.S. Elev
				(m3/s)	(m3/s)	(m3/s)	(m3/s)	(m/s)	(m/s)	(m/s)	(m)
Southern Tributary	Southern Trib	674	20yr	7.9		7.9			0.08		367.82
Southern Tributary	Southern Trib	674	50yr	14.1		14.1			0.07		368.36
Southern Tributary	Southern Trib	674	100yr	19.6		19.6			0.09		368.5
Southern Tributary	Southern Trib	674	200yr	23.1		23.1			0.1		368.55
Southern Tributary	Southern Trib	674	PMF	95.6		95.6			0.32		368.93
Southern Tributary	Southern Trib	664		**Bimbi Rd**							
Southern Tributary	Southern Trib	654	20yr	7.9		7.9			0.37		367.17
Southern Tributary	Southern Trib	654	50yr	14.1		14.1			0.45		367.26
Southern Tributary	Southern Trib	654	100yr	19.6		19.6			0.49		367.33
Southern Tributary	Southern Trib	654	200yr	23.1		23.1			0.52		367.36
Southern Tributary	Southern Trib	654	PMF	95.6		95.6			0.86		367.75
Southern Tributary	Southern Trib	614	20yr	7.9		7.9			0.62		366.96
Southern Tributary	Southern Trib	614	50yr	14.1		14.1			0.73		367.04
Southern Tributary	Southern Trib	614	100yr	19.6		19.6			0.78		367.1
Southern Tributary	Southern Trib	614	200yr	23.1		23.1			0.82		367.13
Southern Tributary	Southern Trib	614	PMF	95.6		95.6			1.12		367.5
Southern Tributary	Southern Trib	533	20yr	7.9	1.94	5.09	0.87	0.15	0.45	0.18	366.59
Southern Tributary	Southern Trib	533	50yr	14.1	4.78	7.67	1.65	0.19	0.52	0.21	366.67
Southern Tributary	Southern Trib	533	100yr	19.6	7.63	9.65	2.32	0.23	0.58	0.23	366.72
Southern Tributary	Southern Trib	533	200yr	23.1	9.5	10.83	2.77	0.25	0.61	0.24	366.75
Southern Tributary	Southern Trib	533	PMF	95.6	48.69	32.56	14.34	0.53	1.04	0.4	367.09
Southern Tributary	Southern Trib	493	20yr	7.9	1.54	5.54	0.82	0.18	0.57	0.23	366.44
Southern Tributary	Southern Trib	493	50yr	14.1	3.35	9.2	1.54	0.27	0.83	0.33	366.48
Southern Tributary	Southern Trib	493	100yr	19.6	5.55	11.81	2.24	0.31	0.92	0.37	366.52
Southern Tributary	Southern Trib	493	200yr	23.1	6.86	13.57	2.67	0.34	1.02	0.41	366.53
Southern Tributary	Southern Trib	493	PMF	95.6	44.47	39.1	12.03	0.81	1.77	0.69	366.75
Southern Tributary	Southern Trib	483		**Culvert**							

River	Reach	River Station	Profile	Q Total	Q Left	Q Channel	Q Right	Vel Left	Vel Chnl	Vel Right	W.S. Elev
				(m3/s)	(m3/s)	(m3/s)	(m3/s)	(m/s)	(m/s)	(m/s)	(m)
Southern Tributary	Southern Trib	473	20yr	7.9	1.55	5.52	0.83	0.18	0.56	0.23	366.32
Southern Tributary	Southern Trib	473	50yr	14.1	4.3	8.16	1.64	0.2	0.6	0.24	366.42
Southern Tributary	Southern Trib	473	100yr	19.6	7.11	10.19	2.3	0.25	0.66	0.26	366.46
Southern Tributary	Southern Trib	473	200yr	23.1	8.92	11.45	2.73	0.27	0.69	0.28	366.49
Southern Tributary	Southern Trib	473	PMF	95.6	47.62	34.67	13.31	0.62	1.26	0.48	366.76
Southern Tributary	Southern Trib	433	20yr	7.9	1.15	5.98	0.77	0.22	0.73	0.3	366.02
Southern Tributary	Southern Trib	433	50yr	14.1	2.09	10.64	1.38	0.39	1.28	0.53	366.02
Southern Tributary	Southern Trib	433	100yr	19.6	3.84	13.71	2.05	0.44	1.4	0.57	366.06
Southern Tributary	Southern Trib	433	200yr	23.1	5.15	15.46	2.49	0.47	1.45	0.59	366.08
Southern Tributary	Southern Trib	433	PMF	95.6	47.88	34.21	13.51	0.6	1.21	0.46	366.52
Southern Tributary	Southern Trib	100	20yr	7.9		6.32	1.58		1.14	0.32	363.65
Southern Tributary	Southern Trib	100	50yr	14.1	0.3	7.48	6.32	0.18	0.82	0.28	364.16
Southern Tributary	Southern Trib	100	100yr	19.6	0.78	8.58	10.24	0.2	0.78	0.28	364.44
Southern Tributary	Southern Trib	100	200yr	23.1	0.63	9.93	12.54	0.14	0.88	0.32	364.48
Southern Tributary	Southern Trib	100	PMF	95.6	16.03	27.58	51.99	0.42	1.94	0.84	364.89
Southern Tributary	Southern Trib	60	20yr	7.9	0.02	5.5	2.38	0.1	0.82	0.26	363.55
Southern Tributary	Southern Trib	60	50yr	14.1	0.53	6.36	7.21	0.15	0.59	0.21	364.14
Southern Tributary	Southern Trib	60	100yr	19.6	1.51	7.65	10.44	0.08	0.6	0.19	364.42
Southern Tributary	Southern Trib	60	200yr	23.1	2.23	8.67	12.2	0.1	0.67	0.21	364.46
Southern Tributary	Southern Trib	60	PMF	95.6	20.02	24.05	51.53	0.36	1.56	0.59	364.79
Southern Tributary	Southern Trib	50		**Holy Camp Rd**							
Southern Tributary	Southern Trib	40	20yr	7.9		6.98	0.92		1.47	0.35	363.18
Southern Tributary	Southern Trib	40	50yr	14.1	0.01	10.42	3.67	0.15	1.68	0.5	363.39
Southern Tributary	Southern Trib	40	100yr	19.6	0.09	12.98	6.54	0.27	1.82	0.58	363.52
Southern Tributary	Southern Trib	40	200yr	23.2	0.18	14.49	8.53	0.33	1.9	0.62	363.6
Southern Tributary	Southern Trib	40	PMF	64.9	1.77	27.91	35.22	0.4	2.46	0.91	364.13

River	Reach	River Station	Profile	Q Total	Q Left	Q Channel	Q Right	Vel Left	Vel Chnl	Vel Right	W.S. Elev
				(m3/s)	(m3/s)	(m3/s)	(m3/s)	(m/s)	(m/s)	(m/s)	(m)
Southern Tributary	Southern Trib	0	20yr	7.9	0	6.03	1.87	0.07	1.02	0.3	363
Southern Tributary	Southern Trib	0	50yr	14.1	0.06	9.3	4.73	0.2	1.3	0.41	363.18
Southern Tributary	Southern Trib	0	100yr	19.6	0.2	11.83	7.57	0.27	1.49	0.49	363.29
Southern Tributary	Southern Trib	0	200yr	23.2	0.32	13.35	9.53	0.32	1.59	0.54	363.35
Southern Tributary	Southern Trib	0	PMF	64.9	1.67	27.34	35.9	0.31	2.37	0.89	363.81
Southern Tributary	Southern Trib	-250	20yr	7.9	0.08	4.82	3	0.14	0.74	0.21	362.14
Southern Tributary	Southern Trib	-250	50yr	14.1	0.35	6.29	7.46	0.19	0.82	0.31	362.24
Southern Tributary	Southern Trib	-250	100yr	19.6	0.7	7.41	11.49	0.23	0.87	0.37	362.32
Southern Tributary	Southern Trib	-250	200yr	23.2	0.97	8.1	14.13	0.25	0.91	0.4	362.36
Southern Tributary	Southern Trib	-250	PMF	64.9	6.01	14.76	44.13	0.4	1.15	0.63	362.71