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APPENDIX 8 – CAPTURE ZONES,
COMMUNITY WATER SUPPLY WELLS



CAPTURE ZONES, COMMUNITY WATER SUPPLY WELLS
R. POTTER, 1996.

TO: LINDA ADAMS, ISLANDS TRUST, GANGES BC

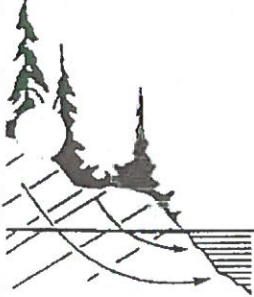
JAN 26, 1996

FILE 2408

"CAPTURE ZONES", COMMUNITY WATER SUPPLY WELLS.
FOR THE ISLANDS TRUST, SALTSRING ISLAND B.C.

BY ROBERT POTTER P.Eng.

GULF ISLANDS GROUNDWATER
184 HILLCREST DRIVE
SALTSRING ISLAND B.C.
V8K 1Y4



GULF ISLANDS
GROUND WATER

Tel: 604 653-9729
Fax: 604 653-0700

ROBERT POTTER MSc P Eng

GEOLOGICAL ENGINEER

184 Hillcrest Drive

Salt Spring Island V8K 1Y4

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1.0 INTRODUCTION

Gulf Islands Groundwater was requested by The Islands Trust to carry out a preliminary assessment of the capture zones of seven community water supply well systems on Saltspring Island.

The systems are:

Scott Point
Cedar Lane
Harbour View
Maracaibo Estates
Cedars of Tuam
Erskine Heights
Mt. Belcher

The assessment was based on data from published geological and topographic maps and on published hydrogeological data for the rock types found within each community area. Available site specific data included approximate well locations, drillers well logs and bail test capacities for some wells, and average pumping rates for each system. No field work was carried out during the course of this project.

Definition: Capture zone is herein considered to be that volume of an aquifer from which water is supplied to a well or system of wells. The output of this report will be surface projections of capture zone estimates.

The procedure followed was that of defining the limits of capture zones as per the following steps.

1/ Define local geological and topographic boundaries.

2/ Select expected values of effective hydraulic conductivities and porosities for each system from published ranges of values for the lithologies of the respective aquifers.

3/ Model the flow to each system during an active recharge period treating each system as a continuum with respect to aquifer parameters and assuming homogeneity and isotropism.

4/ Model flow during the assumed 100 day zero recharge period of summer.

5/ Consider how these idealized models would differ under real world conditions in which flow is controlled by discrete fracture zones of unknown dimensions with hydraulic conductivities which are orders of magnitude greater than the assumed values.

It was found that the systems could be grouped into two types; one in which flow is largely governed by gradients induced by pumping (relatively flat topography), and one in which flow is largely induced by topographic gradients. Due to the time constraints of this exercise and the major uncertainties of data, the modelling procedure outlined above was carried out for these two cases and the results applied to each of the seven community well systems. Type 1 (flat topography) was applied to Scott Point, Cedar Lane, Harbour View, and Maracaibo Estates. Type 2 (sloping topography) was applied to Cedars of Tuam, Erskine Heights, and Mount Belcher.

Computer modeling for this study was carried out with the use of the "Visual Modflow" package of Waterloo Hydrogeologic of Waterloo Ontario. This is an integrated 3-D modelling platform which utilizes the USGS's MODFLOW and MODPATH finite difference codes.

Basemaps for the study were provided by Jacqueline Booth and Associates from the TRIM data base.

2.0 LOCAL HYDROGEOLOGY

The bedrock geology of northern Saltspring Island is that of Cretaceous age shale, sandstone, and conglomerate. These rocks are folded along northwesterly trending axes which gives rise to the characteristic ridge and valley topographic pattern of the area. At the time of deposition the Cretaceous rocks would have had high intergranular porosities. Subsequent infilling by cementing material has, however, all but eliminated these voids. Folding and faulting at later times has produced the fracture systems which currently exist. Fractures are generally larger and more prevalent in the relatively brittle sandstones and conglomerates than in the more ductile shales. Below the water table the voids of these fractures are water filled and constitute the geometrically complex aquifers of northern Saltspring Island.

The geology of the southern part of the island is dominated by Palaeozoic volcanic and intrusive rocks. These have been subjected numerous periods of deformation and in general are more intensely fractured than the sedimentary rocks to the north.

The level of the water table and therefore the quantity of water stored in the subsurface varies with the seasons of the year. A typical annual cycle would see the water table at or near the topographic surface during the high rainfall months of midwinter. As precipitation decreases and eventually ceases in spring and summer the water table will fall gradually in response to gravity flow, evapotranspiration, and withdrawal from wells. It will

reach its lowest level at the end of the summer dry period. With the heavy precipitation of autumn the system will be rapidly recharged to complete the cycle about year end. The amount of fluctuation between the extremes of high and low water table levels and the variation of this parameter from place to place are functions of the geometry and hydraulic conductivities of the fracture system.

3.0 MODELS

3.1 Horizontal Model

Figure 1 shows the configuration of head values within the modeled sector of the Scott Point area with 2 wells pumping at $8.33 \text{ m}^3/\text{day}$.

Assumed aquifer constants:

Hydraulic conductivity $K=1 \times 10^{-1} \text{ m/sec}$

Porosity $n=.001$

1A: Steady state head with an infiltration rate (R) of 400 mm/yr .

1B: Transient head values with an infiltration rate of 0 mm/yr at time = 10 days.

1C: Transient head values with an infiltration rate of 0 mm/yr at time = 100 days.

Note that the areas contributing water to the pumping wells, as defined by areas having head gradients toward the wells, increase as the water table declines with time. These areas reach their maximum sizes at $t=100$ days (end of the dry period) and will begin to decrease as the aquifer is recharged.

Figures 2,3, and 4 show the effects of gravity induced drainage and pumping on the head values on a section through well 1. These show clearly the limited areas which are contributing water directly to the well.

Figure 5 shows the 100 day pathlines of flow to a pumping well in a flat aquifer with no recharge (Cedar Lane, summer).

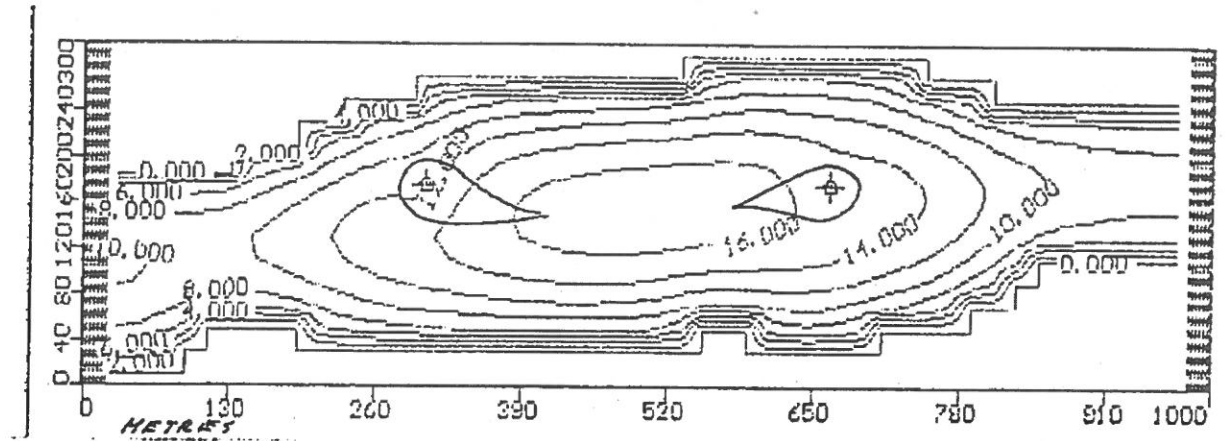
Pumping rate $Q=12 \text{ m}^3/\text{day}$

Assumed aquifer constants: $K=1 \times 10^{-1} \text{ m/sec}$

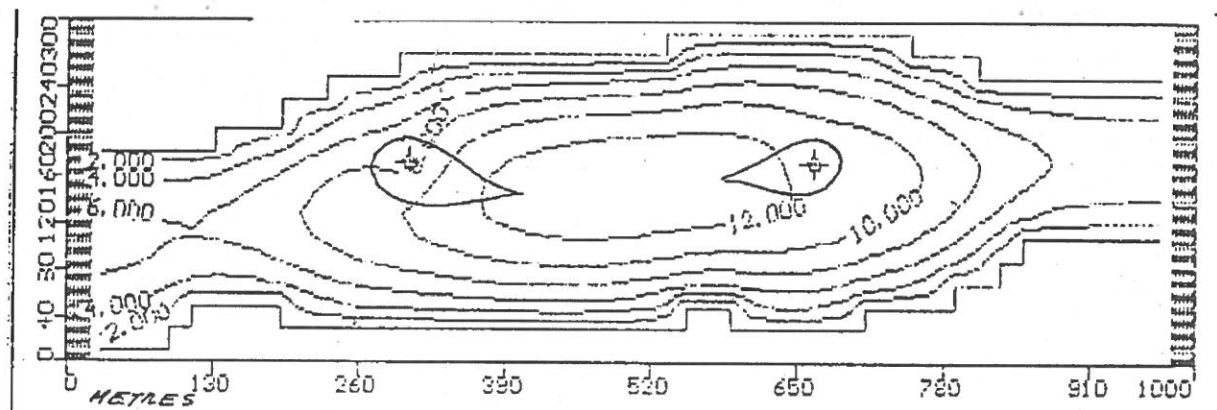
$n=.001$

The pathlines here have an average length of about 10 metres. The same model run with a porosity of .0001 (Figure 6) shows the 100 day pathlines to be about 50 metres long. The capture zone for this well during the dry period can be considered as that of a circular area of radius between 10 and 50 metres depending on the porosity of the system.

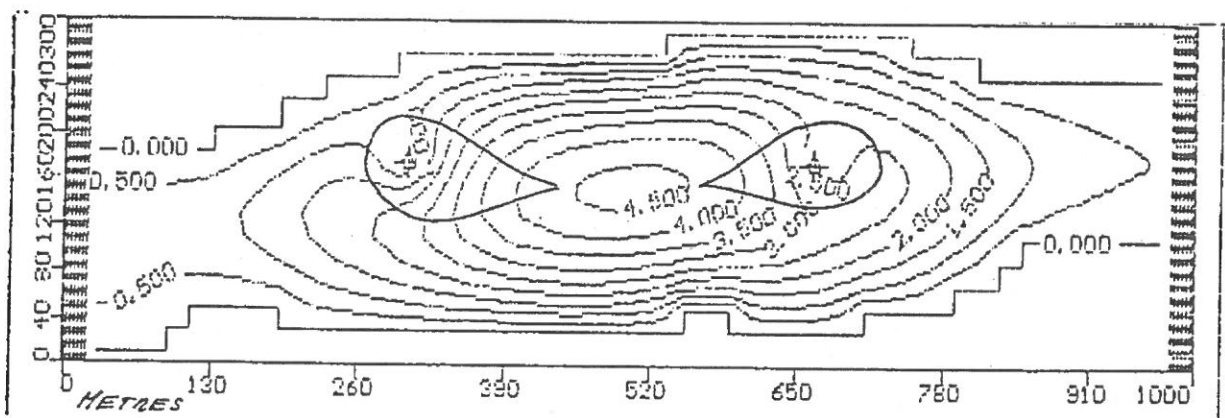
It can be concluded that the capture zones surrounding these wells, given the various simplifying assumptions, are probably not more than 100 metres in diameter.



Initial heads



10 days @ R=0



100days @ R=0

Gulf Islands Groundwater - Salt Spring Island
 Project: 2408 CAPTURE ZONES
 Description: SCOTT PT 100days @ R=0
 Modeller: RP
 22 Jan 95

Visual MODFLOW v.1.50, (c) 1995
 Waterloo Hydrogeologic Software
 NC: 58 NR: 19 NL: 7
 Current Layer: 1

FIGURE 1

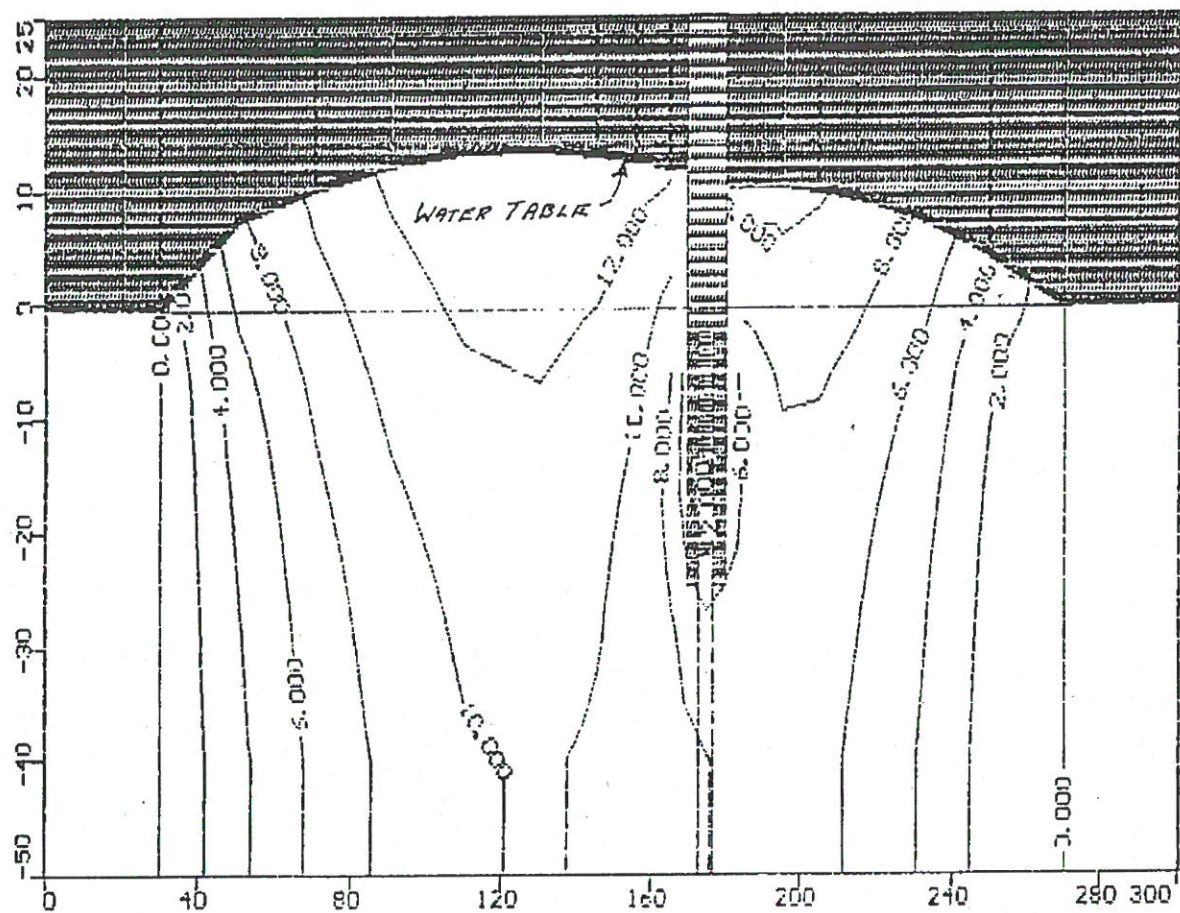


FIGURE 2

Gulf Islands Groundwater - Salispring Island
 Project: 2408 CAPTURE ZONES
 Description: SCOTT PT Initial heads
 Modeller: RP
 22 Jan 96

Visual MODFLOW v.1.50, (c) 1995
 Waterloo Hydrogeologic Software
 NC: 56 NR: 19 NL: 7
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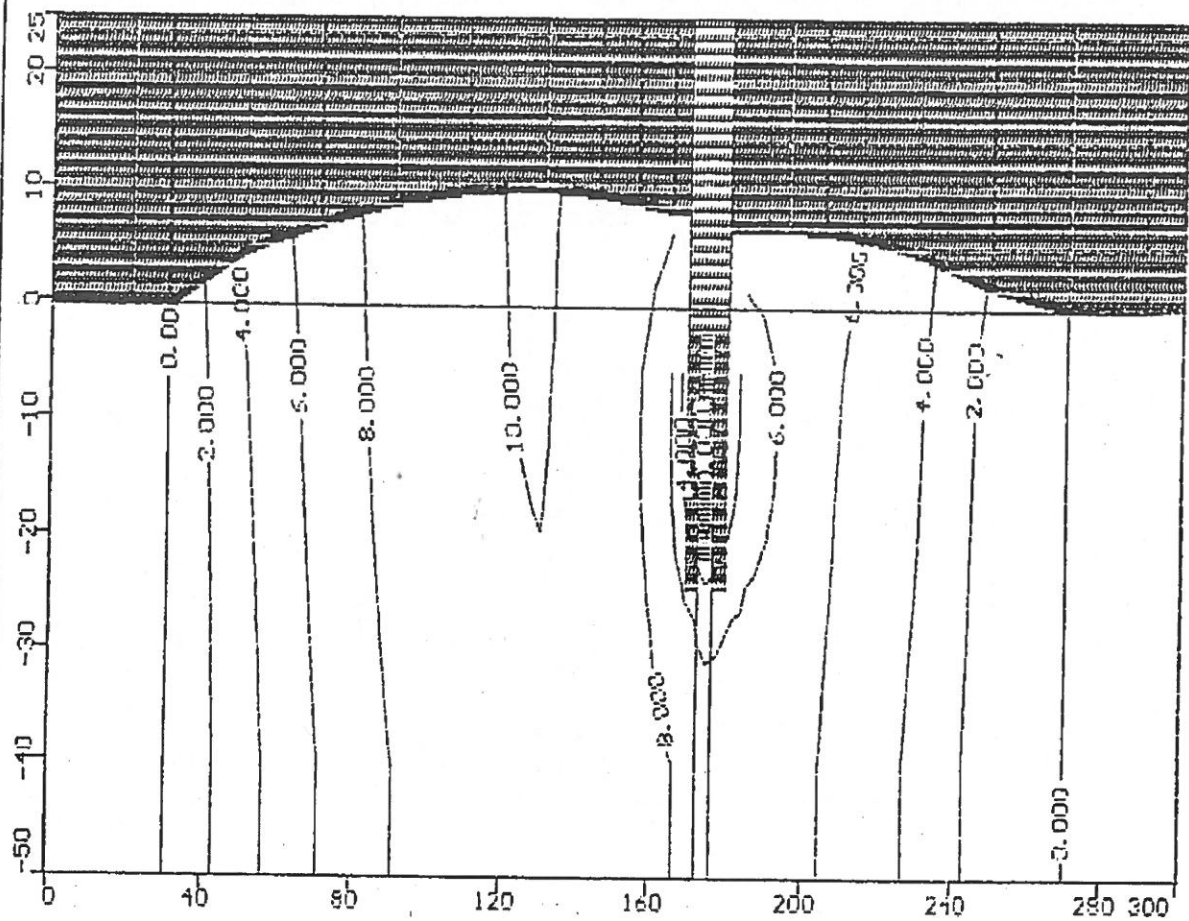


FIGURE 3

Gulf Islands Groundwater - Saltspring Island
 Project: 2408 CAPTURE ZONES
 Description: SCOTT PT 10 days @ R=0
 Modeller: RP
 22 Jan 96

Visual MODFLOW v.1.50, (c) 1995
 Waterloo Hydrogeologic Software
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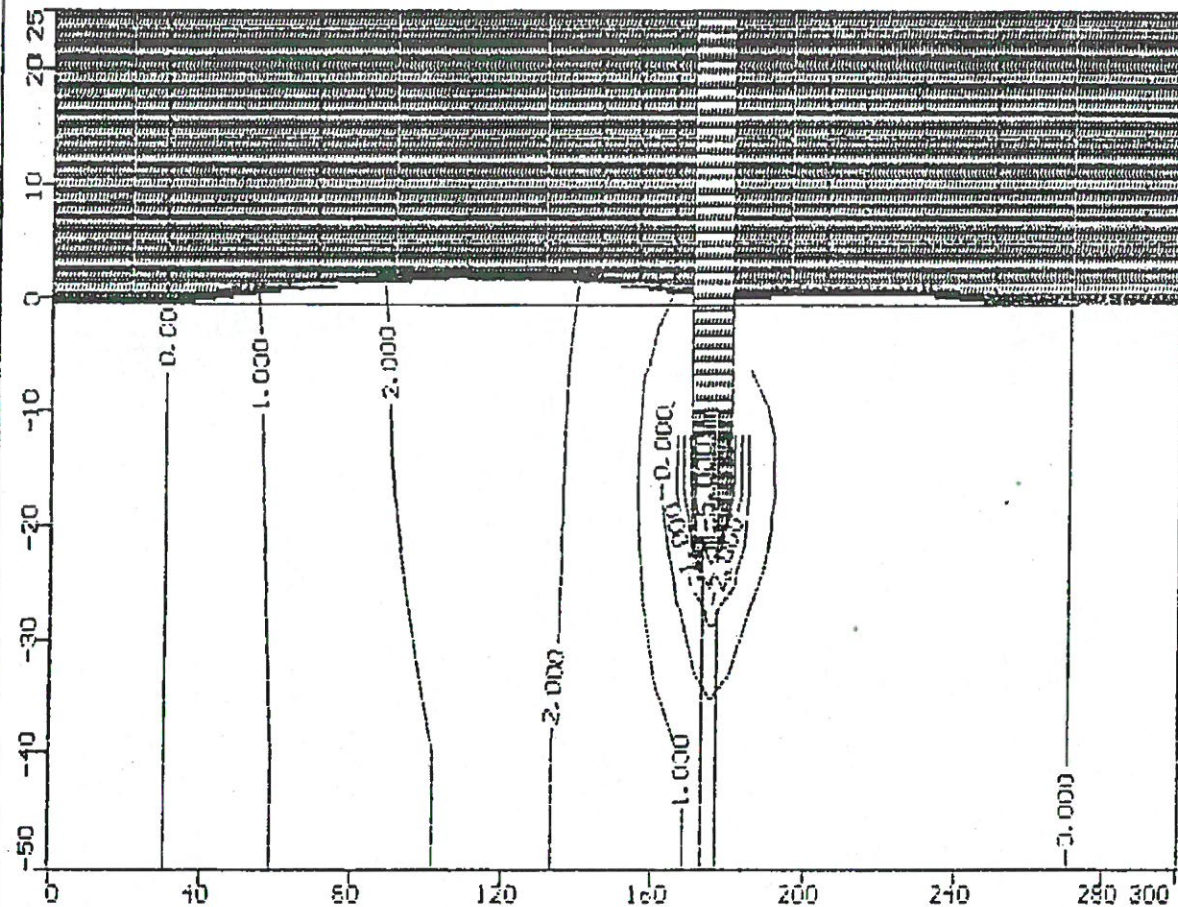
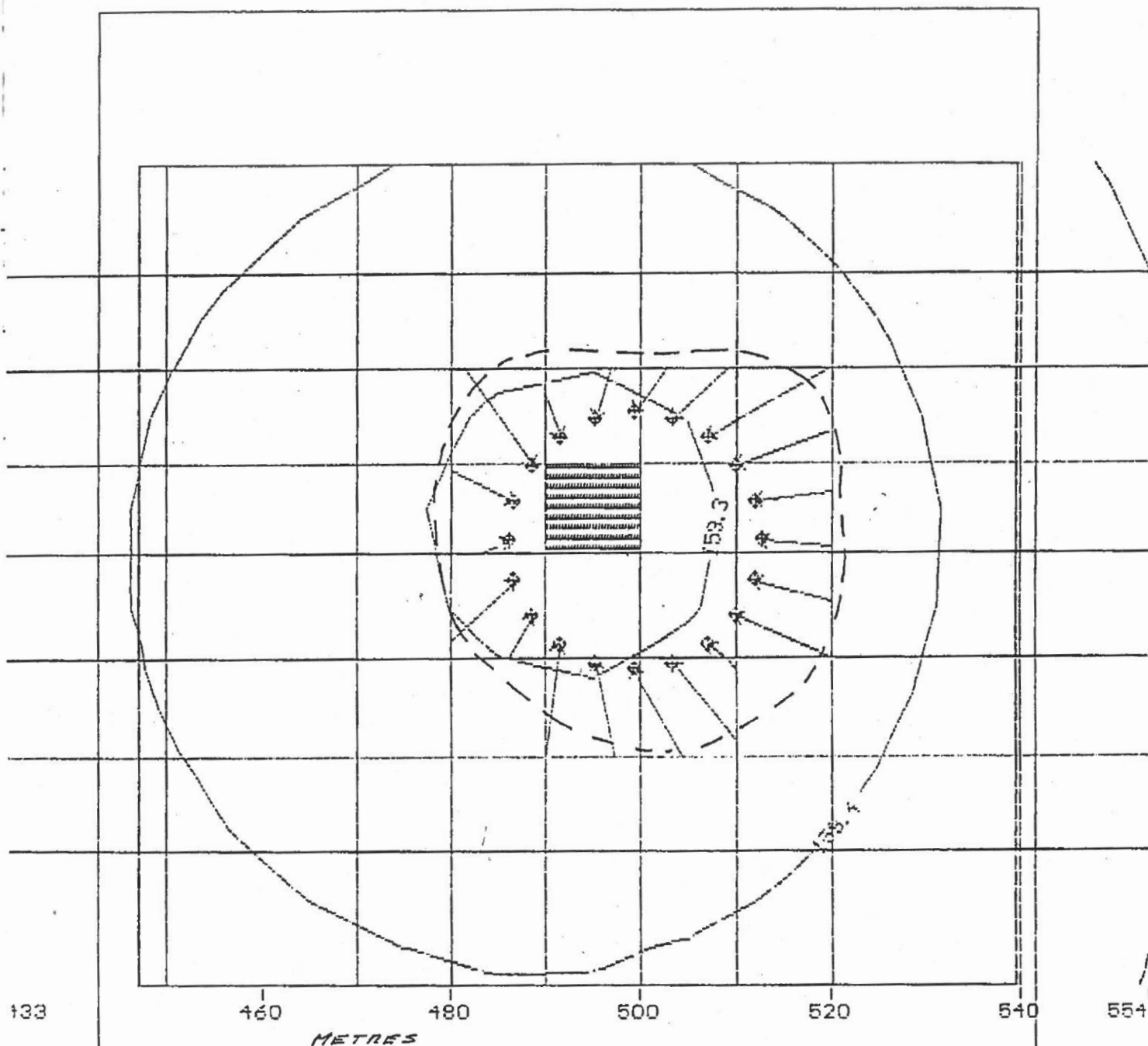


FIGURE 4

Gulf Islands Groundwater - Salispring Island
 Project: 2408 CAPTURE ZONES
 Description: SCOTT PT 100Days @ R=0
 Modeller: RP
 22 Jan 96

Visual MODFLOW v.1.50, (c) 1995
 Waterloo Hydrogeologic Software
 NC: 56 NR: 19 NL: 7
 Current Column: 18

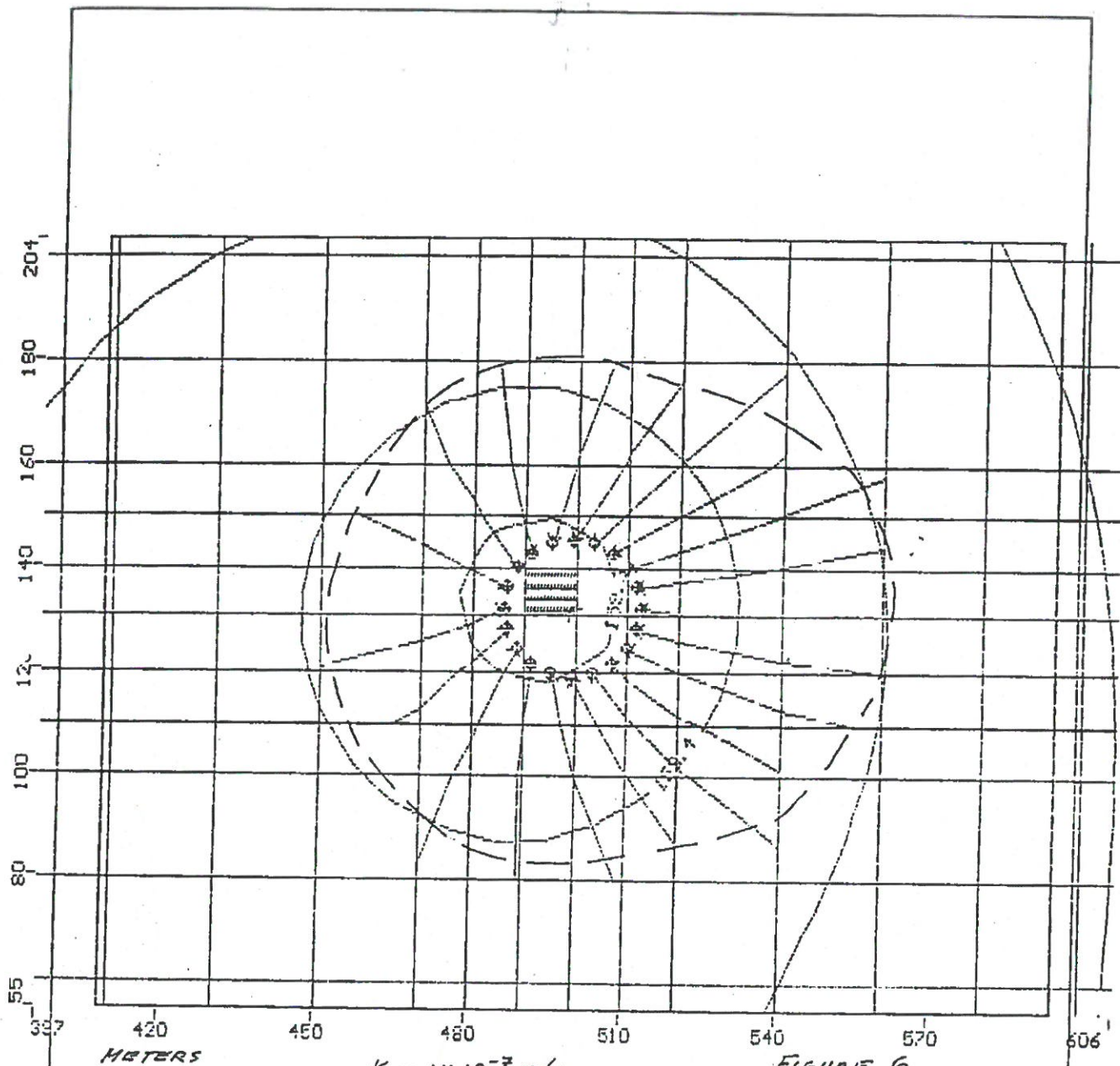


$K = 1 \times 10^{-6} \text{ m/sec}$
 $n = .001$

FIGURE 5
 100 DAY FLOW PATHS
 TO PUMPING WELL
 IN HORIZONTAL AQUIFER

Gulf Islands Groundwater - Saltsp
 Project: 2408 CAPTURE ZONES
 Description: CEDAR LANE n=.001,
 Modeller: RP
 22 Jan 96

Visual MODFLOW v.1.50, (c) 1995
 Waterloo Hydrogeologic Software
 NC: 49 NR: 26 NL: 8
 Current Layer: 5



$K = 1 \times 10^{-7} \text{ m/sec}$
 $n = .0001$

FIGURE 6
 100 DAY FLOW PATHS
 TO PUMPING WELL
 IN HORIZONTAL AQUIFER

Gulf Islands Groundwater - Saltspring Island
 Project: 2408 CAPTURE ZONES
 Description: CEDAR LANE n=.0001
 Modeller: RP
 22 Jan 96

Visual MODFLOW v.1.50, (c) 1995
 Waterloo Hydrogeologic Software
 NC: 49 NR: 26 NL: 8
 Current Layer: 5

If one introduces the reality of planar fracture zones the problem becomes indeterminate. A single fracture zone intersected by a well can extend the capture area of that well over a broad area of the fracture surface which in plan would show as an elongate feature. Without any structural data to indicate the expected direction and width of these features one can only assume a random distribution and an arbitrary length of influence. For this exercise fracture influence will be considered to be radial for a distance of 200 metres.

3.2 Sloping Model

In the case of a well pumping from a sloping homogeneous isotropic aquifer, the capture zone is an elongate feature which extends upslope to the nearest subsurface drainage divide (which in most cases will coincide with a topographic divide).

The width (w) of this feature will be a function of head gradient (i), the pumping rate (Q), the thickness of the flow system (h), and the hydraulic conductivity (K) as shown in figure 7. The head gradient here is assumed to be the slope on surface.

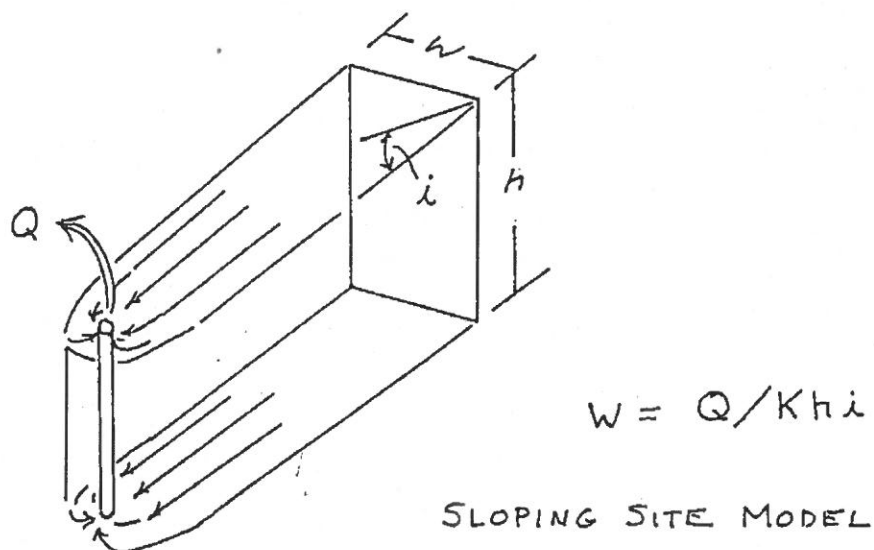


Figure 7

When highly conductive fracture zones of unknown dimensions are added to this simple model it is not possible to define a unique capture zone. It is reasonable to assume however that the zone will be elongated up slope. For this exercise it is assumed that the effects of fracture flow on capture zone geometry can be accommodated by extending a zone for 100 metres beyond that predicted by the simple model.

4.0 RESULTS

4.1 SCOTT POINT

SOURCE OF SUPPLY* : Three wells :

Well #	Depth (m)	Rated capacity (IGPM)
1	35	9
2	43	2
3	13	3

PUMPING RATES : IGPD

Average daily withdrawal: 3500

Maximum daily withdrawal 6000

Dry Summer withdrawal 5500

GEOLOGY:

Cretaceous age Nanaimo Group sediments.

Aquifer comprised of fractured sandstones of the Geoffrey Formation

LIMITS OF AQUIFER:

Narrow peninsula. Seawater constant head boundaries.

Approximate dimensions 200 x 1800 metres.

ASSUMED VALUES OF AQUIFER PARAMETERS:

Hydraulic conductivity $K = 1 \times 10^{-7}$ m/sec, Isotropic

Porosity $n = .001$

MODEL: Horizontal

* Data from Watson 1995

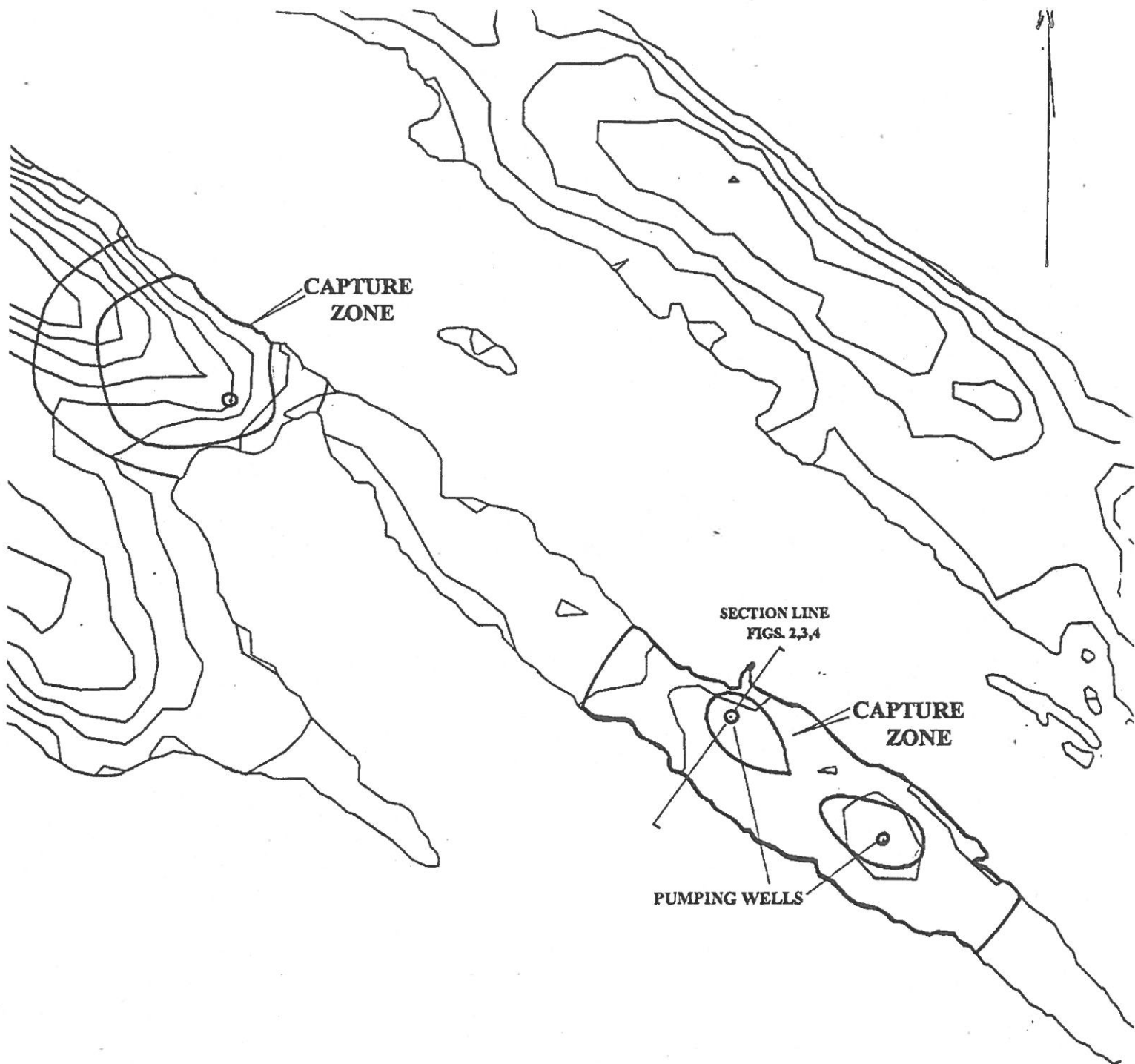


Figure 8
SCOTT POINT
CAPTURE ZONES
Scale 1:10,000

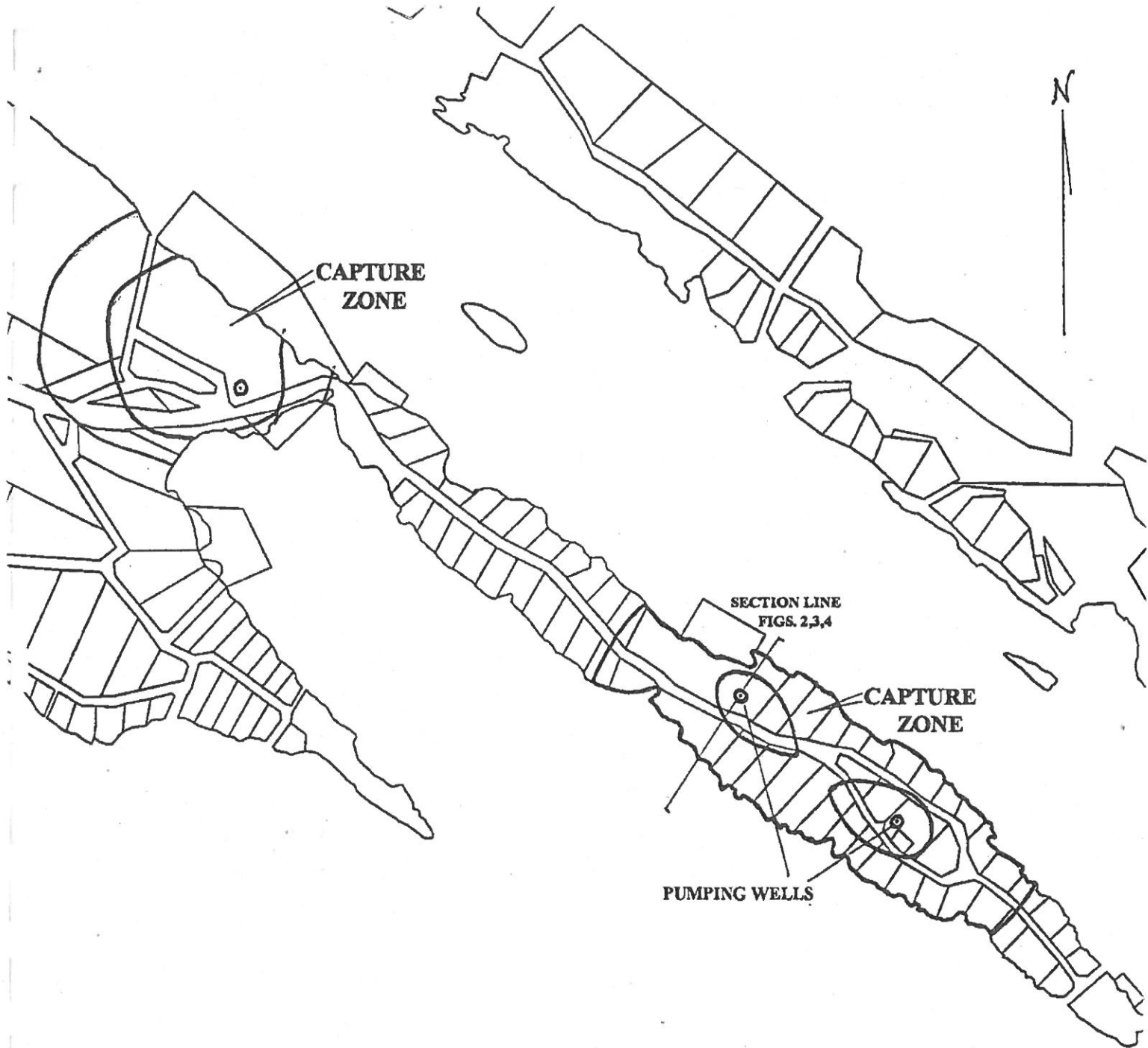


Figure 9
SCOTT POINT
CAPTURE ZONES
Scale 1:10,000

4.2 CEDAR LANE

SOURCE OF SUPPLY¹ : two wells

Well#	Depth (m)	Rated capacity (IGPM)
1	63	4.6
2	37	7

PUMPING RATES¹ : IGPD

Average daily withdrawal: 3500

Maximum daily withdrawal: 6000

Dry summer withdrawal: 5000

GEOLOGY:

Cretaceous age Nanaimo Group sediments.

Aquifer comprises fractured sandstones of the Geoffrey Formation.

LIMITS OF AQUIFER:

The fractured sandstone is bounded to the north and south by significantly less permeable shales of the Spray and Northumberland Formations.

Approximate dimensions 400 x 1000 metres.

ASSUMED VALUES OF AQUIFER PARAMETERS:

Hydraulic conductivity $K = 1 \times 10^{-1}$ m/sec, Isotropic.Porosity $n = .001$

MODEL: Horizontal

¹ Data from Watson 1995

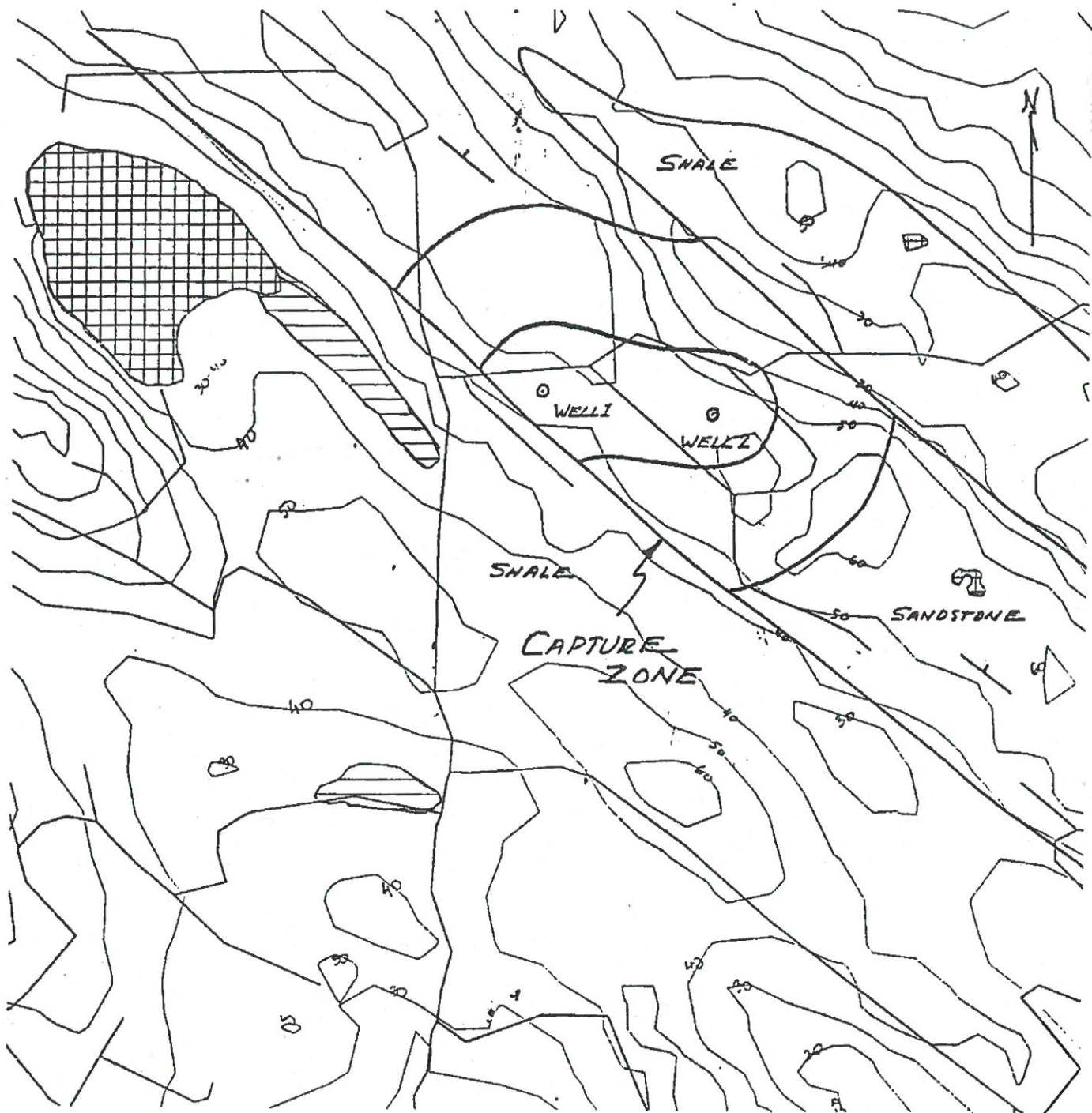


FIGURE 10
CEDAR LANE
CAPTURE ZONE
SCALE 1:10,000



FIGURE 11
CEDAR LANE
CAPTURE ZONE
SCALE 1:10,000

4.3 HARBOUR VIEW

SOURCE OF SUPPLY¹ : Three wells

Well#	Depth (m)	Rated capacity (IGPM)
1	18	3.5
2	27	3.5
3	122	7+

PUMPING RATES¹ : IGPD

Average daily withdrawal: 1,000 to 1,500

Maximum daily withdrawal: 4,000

Dry summer withdrawal: 2,800

GEOLOGY:

Cretaceous age Nanaimo Group sediments.

Aquifer comprises fractured sandstones of the De Courcy Formation.

LIMITS OF AQUIFER:

A relatively impermeable shale unit forms the boundary to the northeast; the southwest limit is a constant head seawater boundary.

Approximate dimensions 200 x 1000 metres.

ASSUMED VALUES OF AQUIFER PARAMETERS:

Hydraulic conductivity $K = 1 \times 10^{-1}$ m/sec, Isotropic.

Porosity $n = .001$

MODEL: Horizontal

¹ Data from Watson 1995

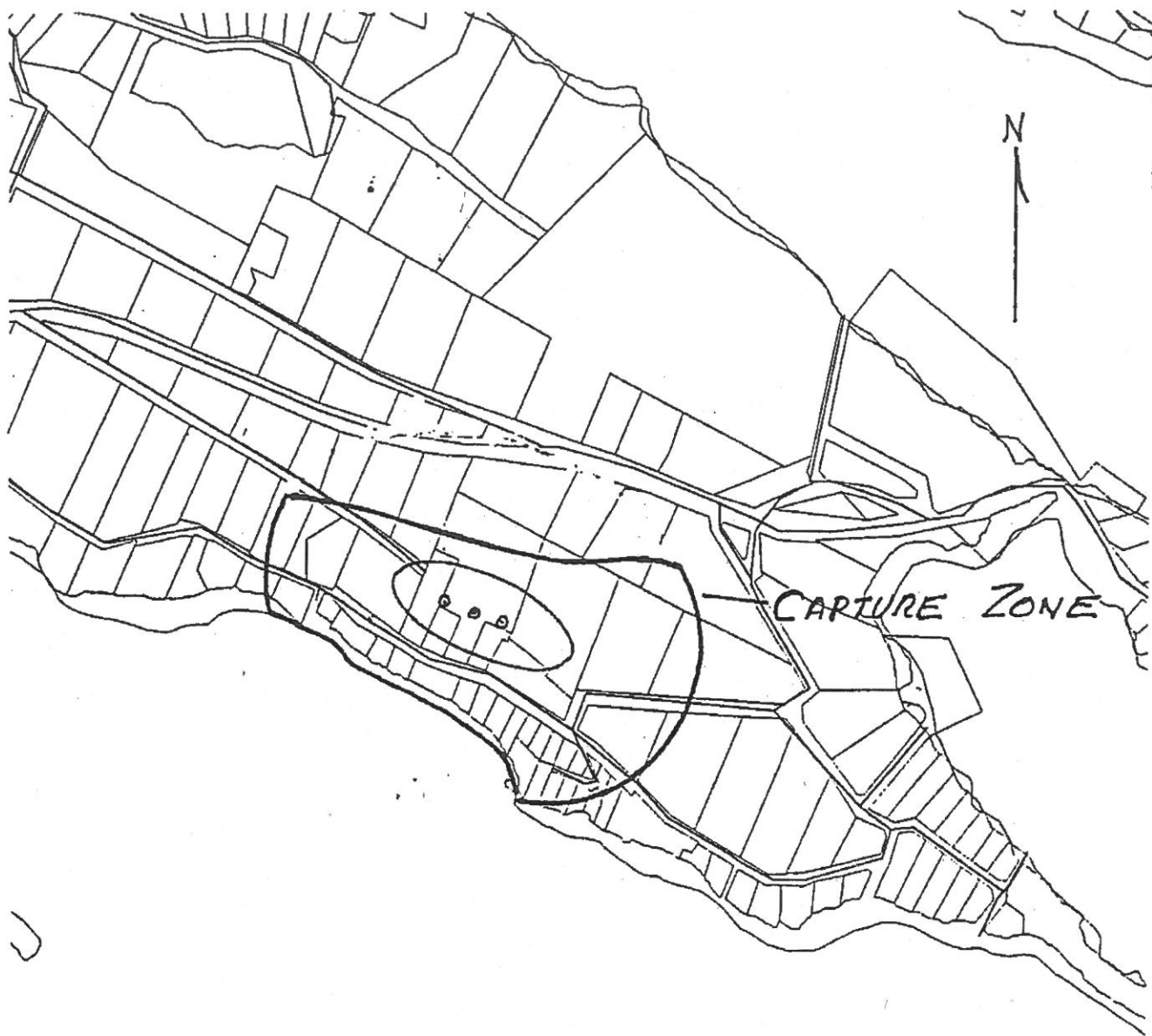


FIGURE 12
HARBOUR VIEW
CAPTURE ZONE
SCALE 1:10,000

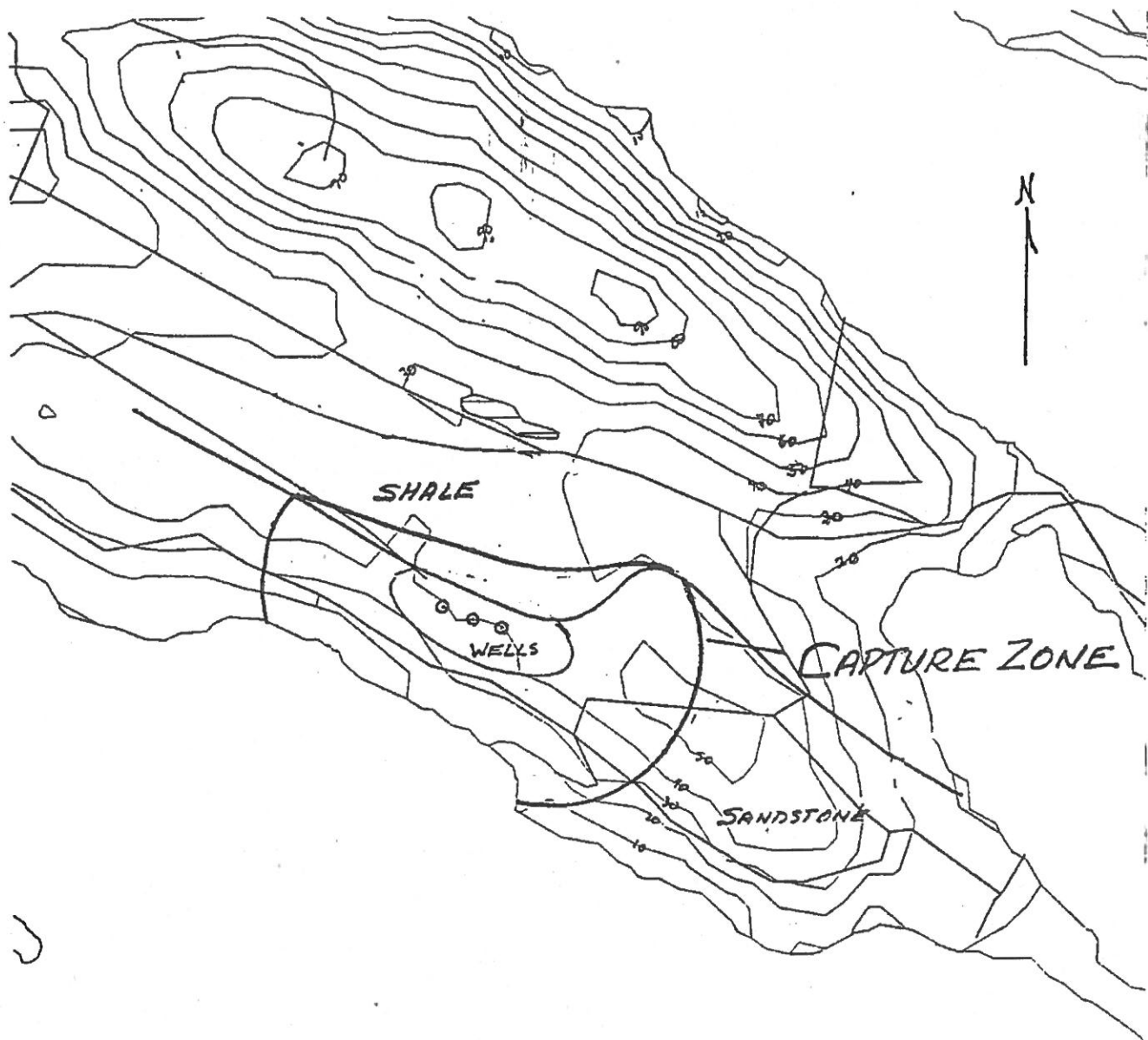


FIGURE 13
HARBOUR VIEW
CAPTURE ZONE
SCALE 1:10,000

4.4 MARACAIBO ESTATES

SOURCE OF SUPPLY¹ : Five wells

Well#	Depth (m)	Rated capacity (IGPM)
77-5	?	40-50
79-6	?	8
89-1	?	12
89-2	?	25
93-2	?	3 to 9

PUMPING RATES¹ : IGPD

Average daily withdrawal: 6,000
 Maximum daily withdrawal: 16,000
 Dry summer withdrawal: 10,000

GEOLOGY:

Cretaceous age Nanaimo Group sediments.
 Aquifer comprises fractured sandstones of the Geoffrey Formation.

LIMITS OF AQUIFER:

Narrow peninsula. Seawater constant head boundaries.
 Approximate dimensions 400 x 4000 metres.

ASSUMED VALUES OF AQUIFER PARAMETERS:

Hydraulic conductivity $K = 1 \times 10^{-1}$ m/sec, Isotropic.
 Porosity $n = .001$

MODEL: Horizontal

¹ Data from Watson 1995

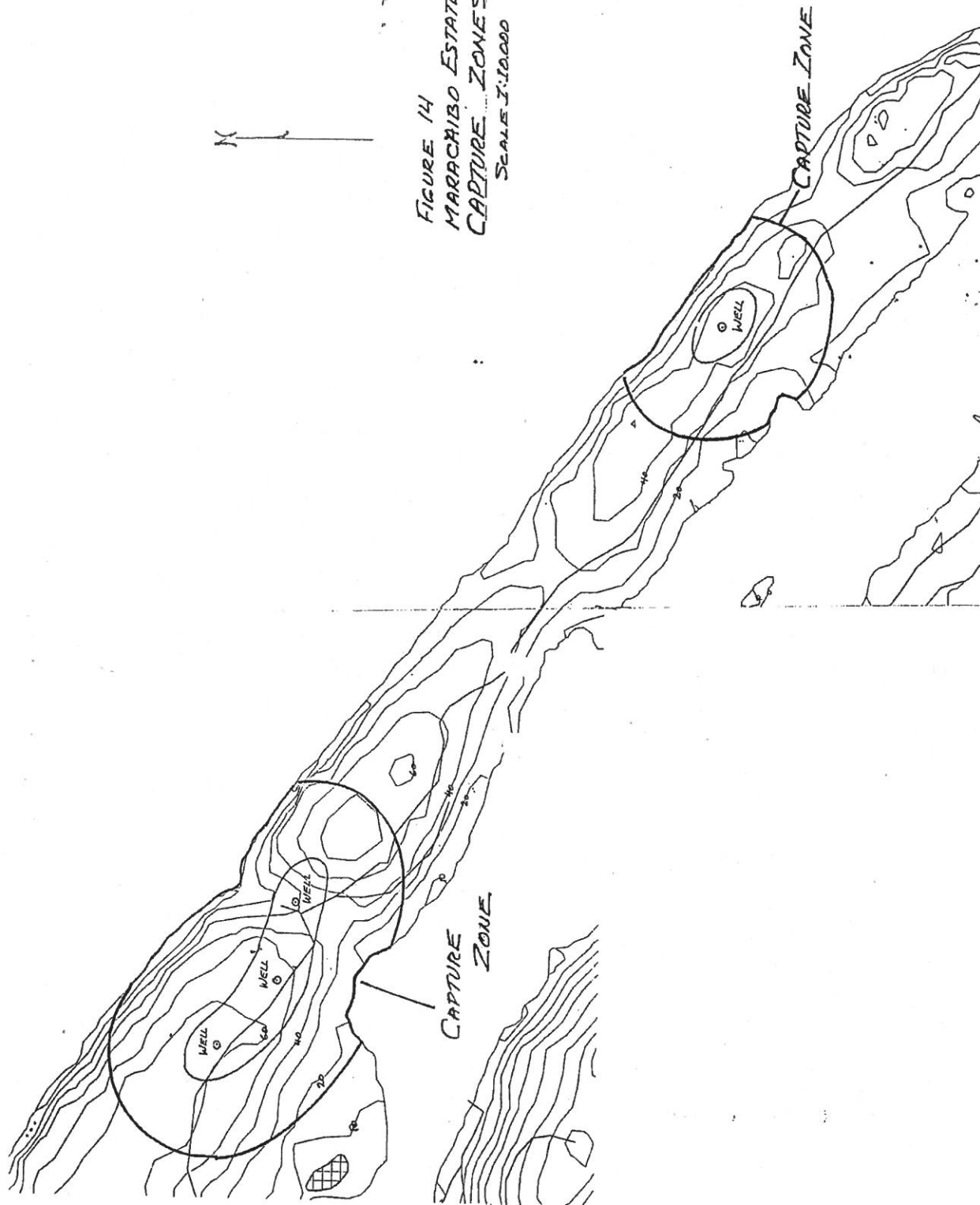
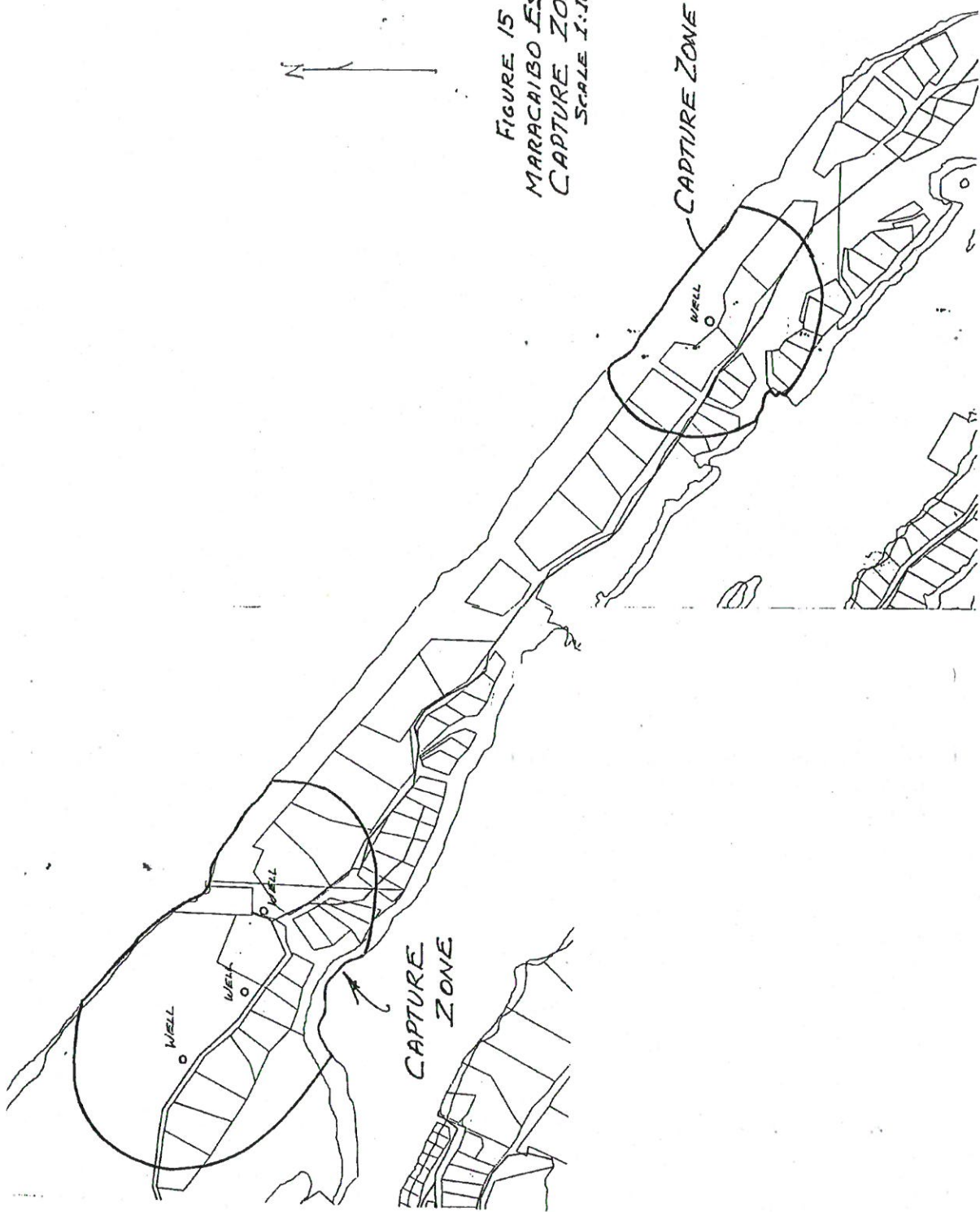


FIGURE 14
MARCHABO ESTATES
CAPTURE ZONES
SCALE 1:10,000

FIGURE 15
MARACAIBO ESTATES
CAPTURE ZONES
SCALE 1:10,000



4.5 CEDARS OF TUAM

SOURCE OF SUPPLY¹ : one well

Well#	Depth (m)	Rated capacity
1	24	800 IGPD (dry season)

PUMPING RATES¹ : IGPD

Average daily withdrawal: 1,400

Maximum daily withdrawal: 2,000

Dry summer withdrawal: 1,500

GEOLOGY:

Lower Devonian Myra Formation.

The aquifer comprises fractured silicic tuffs and breccias.

LIMITS OF AQUIFER:

A broad, but as yet undefined area of the east side of Mt. Tuam.

Approximate dimensions 3000 x 4000 metres.

ASSUMED VALUES OF AQUIFER PARAMETERS:

Hydraulic conductivity $K = 1 \times 10^{-1}$ m/sec, Isotropic.

Porosity $n = .001$

MODEL: Sloping

¹ Data from Watson 1995

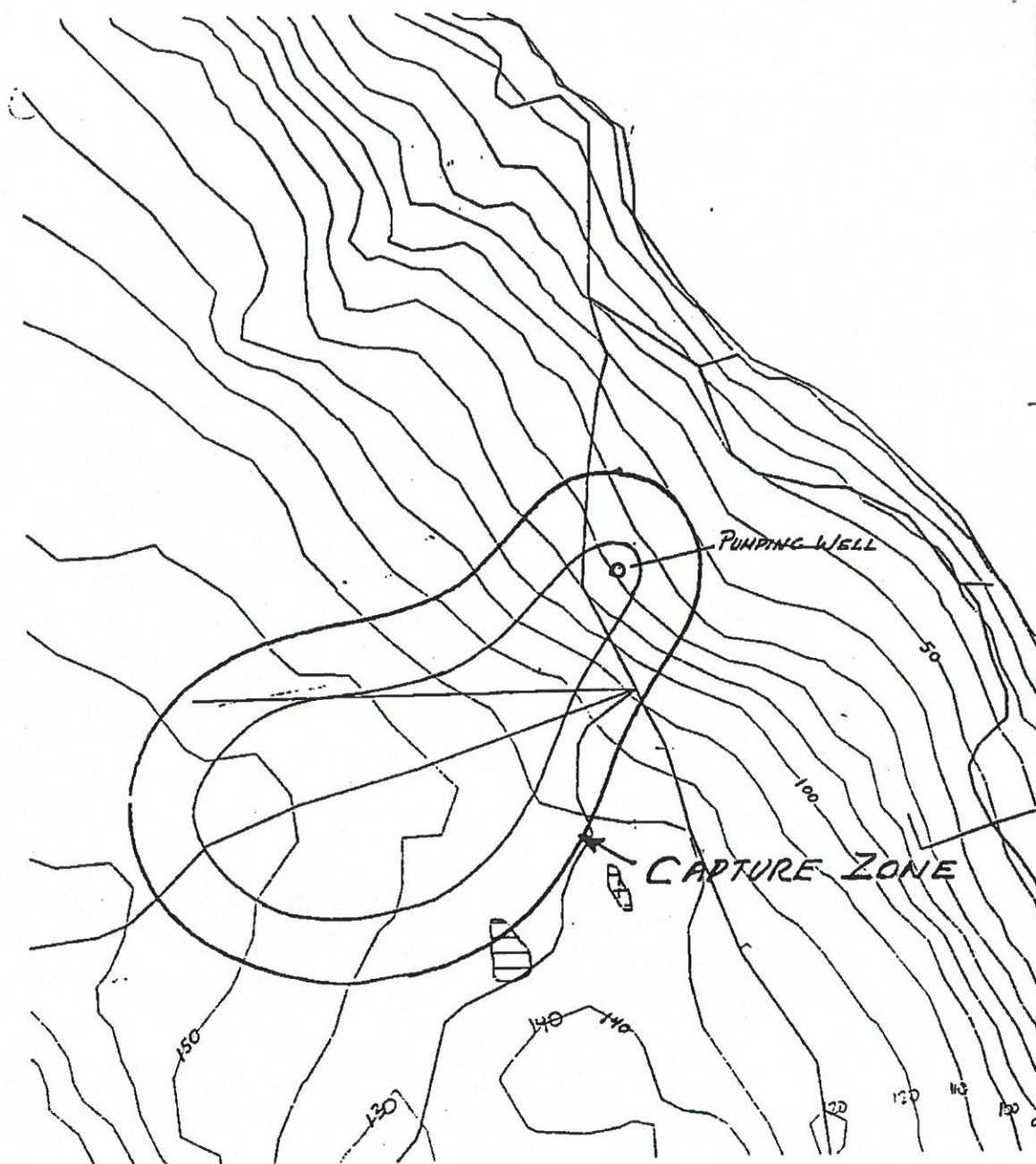


FIGURE 16
CEDARS of TUAM
CAPTURE ZONE
SCALE 1:10,000

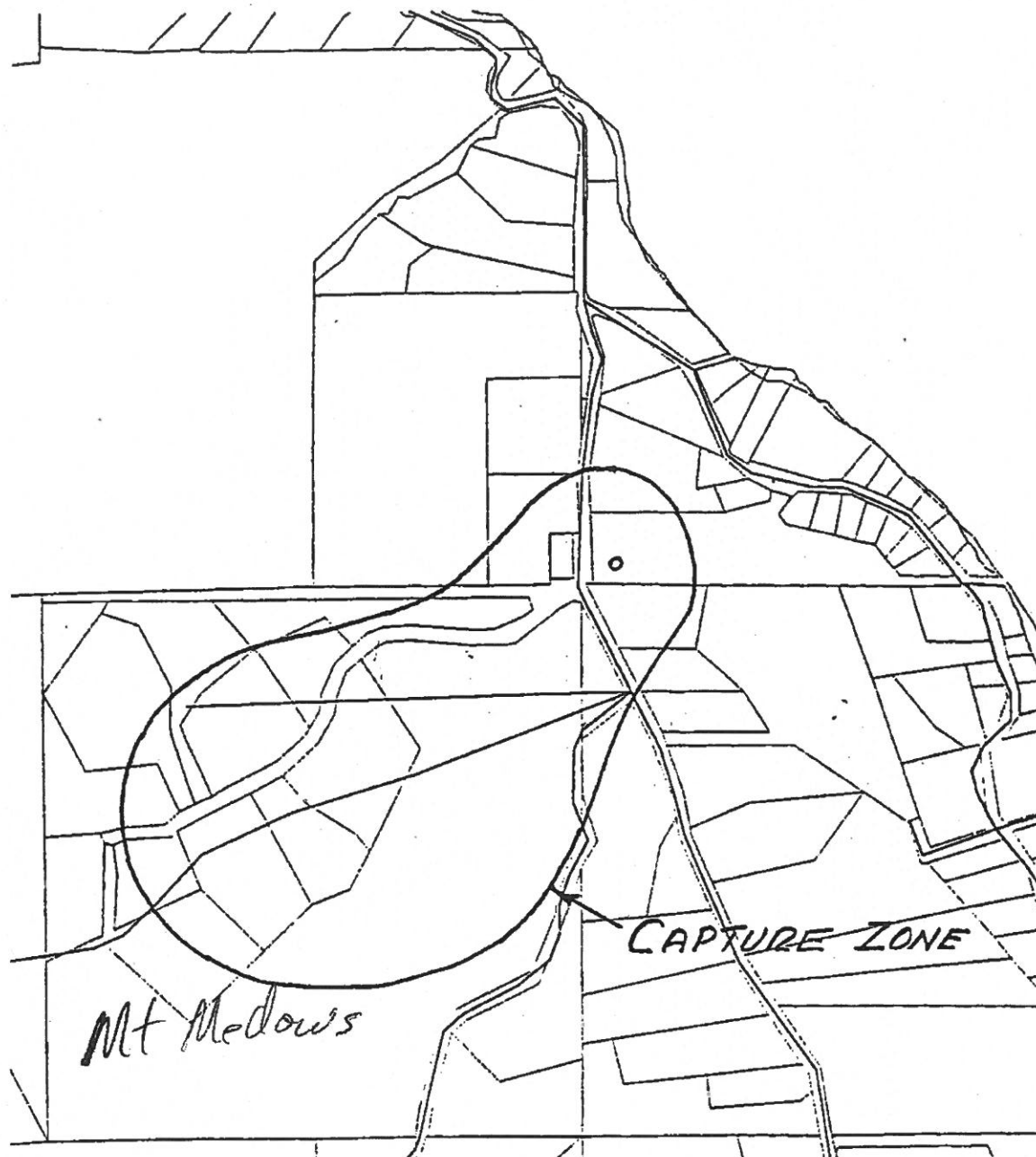


FIGURE 17
CEDARS OF TUAM
CAPTURE ZONE
SCALE 1:10,000

4.6 ERSKINE HEIGHTS

SOURCE OF SUPPLY¹ : Two wells "

Well#	Depth (m)	Rated capacity (IGPM)
1	?	5.5
2	?	5.5

PUMPING RATES¹ : IGPD

Average daily withdrawal: 1,800

Maximum daily withdrawal: 3,500

Dry summer withdrawal: 2,800

GEOLOGY:

Cretaceous age Nanaimo Group sediments.

Aquifer comprises fractured shale and siltstone of the Haslam Formation and fractured sandstone and conglomerate of the Extension-Protection Formation.

LIMITS OF AQUIFER:

A broad ill defined area on the west side of Mt.Erskine.

Approximate dimensions 800 x 1500 metres.

ASSUMED VALUES OF AQUIFER PARAMETERS:

Hydraulic conductivity $K = 1 \times 10^{-1}$ m/sec, Isotropic.

Porosity $n = .001$

MODEL: Sloping.

¹ Data from Watson 1995

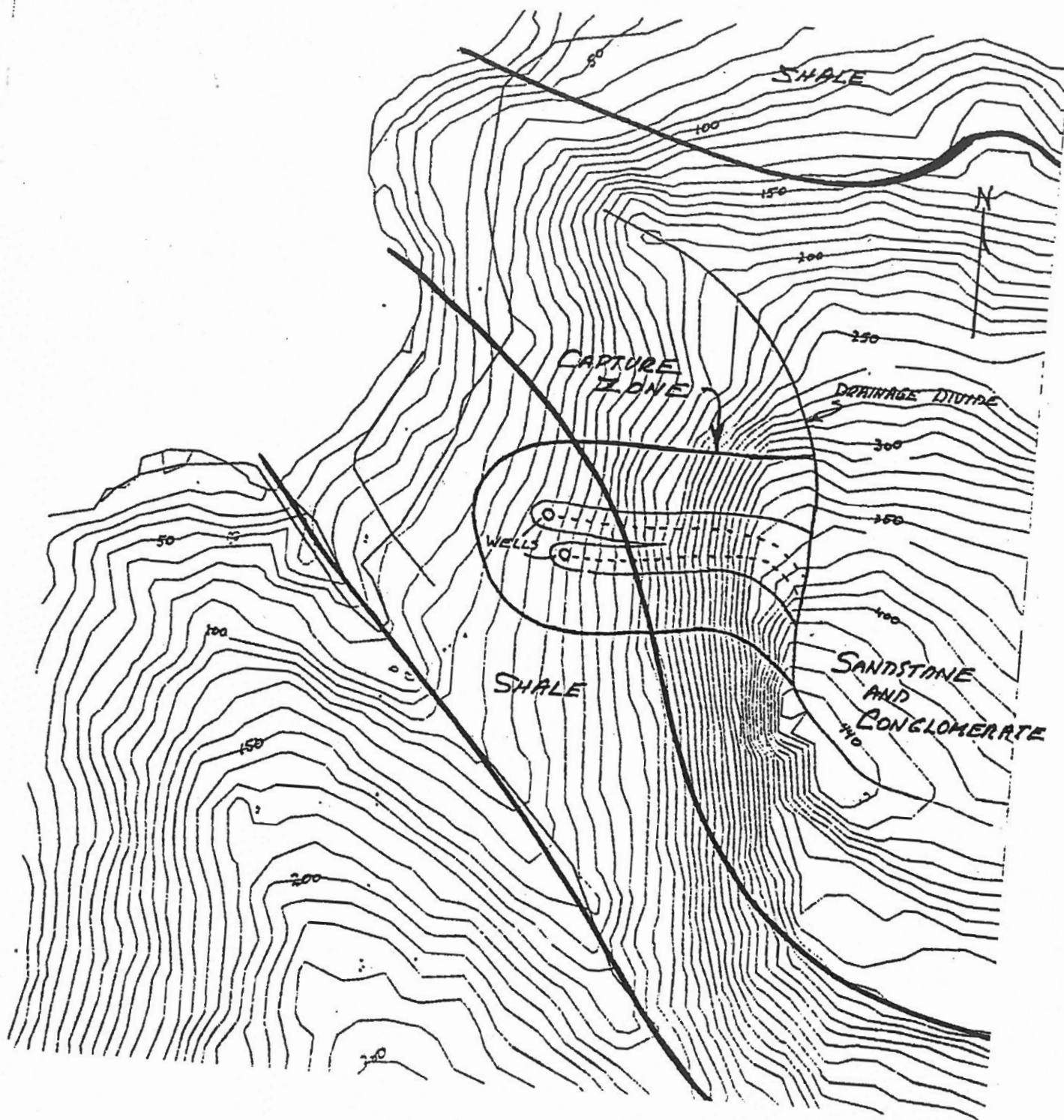


FIGURE 18
ERSKINE HEIGHTS
CAPTURE ZONE
SCALE 1:10,000

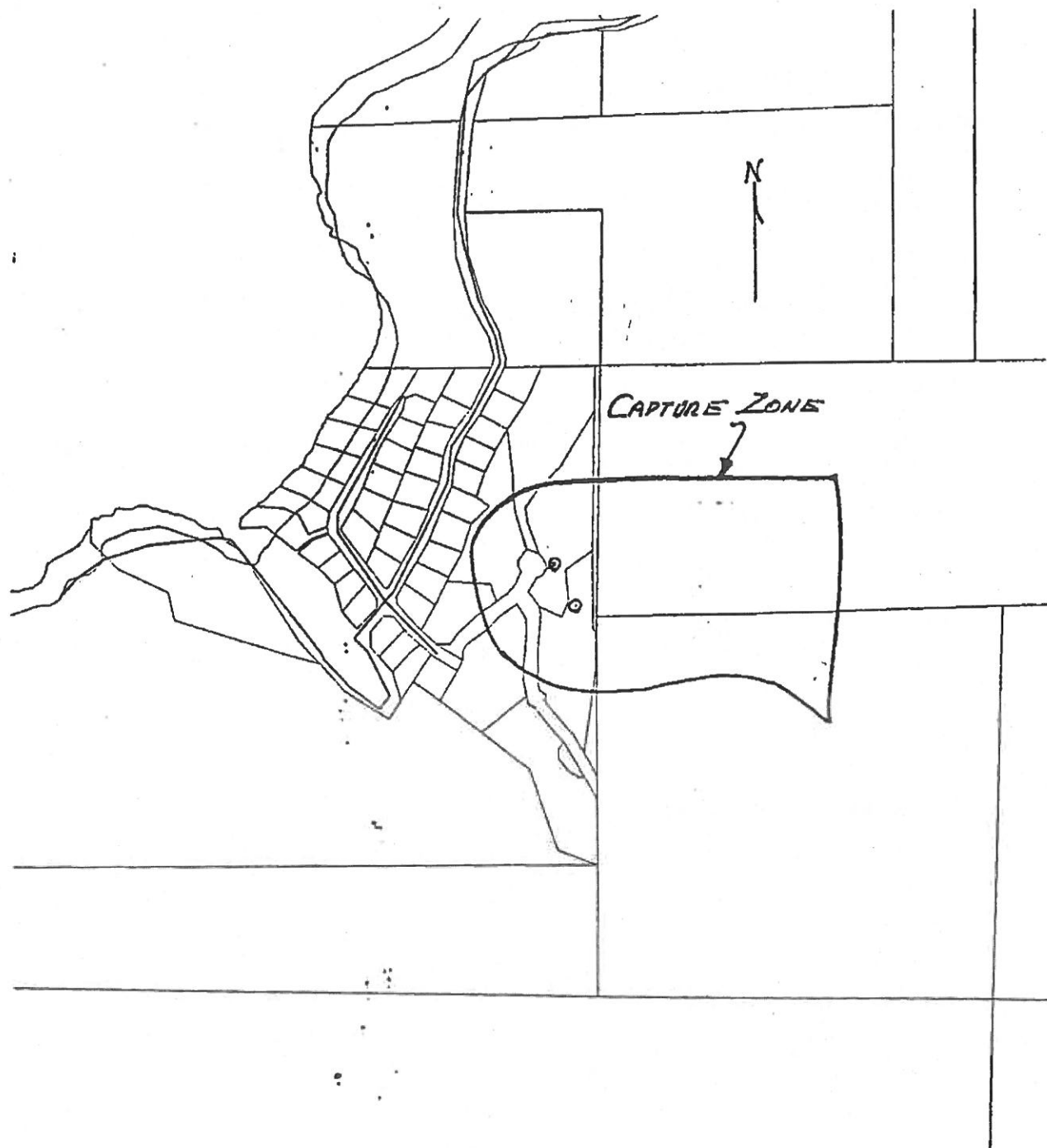


FIGURE 19
ERSKINE HEIGHTS
CAPTURE ZONE
SCALE 1:10,000

4.7 MT. BELCHER

SOURCE OF SUPPLY¹ : Four pumping wells, three standby wells

Well#	Depth (m)	Rated capacity (IGPM)
Depths and capacities unknown.		

PUMPING RATES¹ : IGPD

Average daily withdrawal: 4,000

Maximum daily withdrawal: 8,000

Dry summer withdrawal: 5,700

GEOLOGY:

Cretaceous age Nanaimo Group sediments.

Aquifer comprises fractured conglomerates and sandstones of the Extension- Protection Formation.

LIMITS OF AQUIFER:

A broad area on the northeast flank of Mt. Belcher.

Approximate dimensions 800 x 2000 metres.

ASSUMED VALUES OF AQUIFER PARAMETERS:

Hydraulic conductivity $K = 1 \times 10^{-1}$ m/sec, Isotropic.

Porosity $n = .001$

MODEL: Sloping

¹ Data from Watson 1995

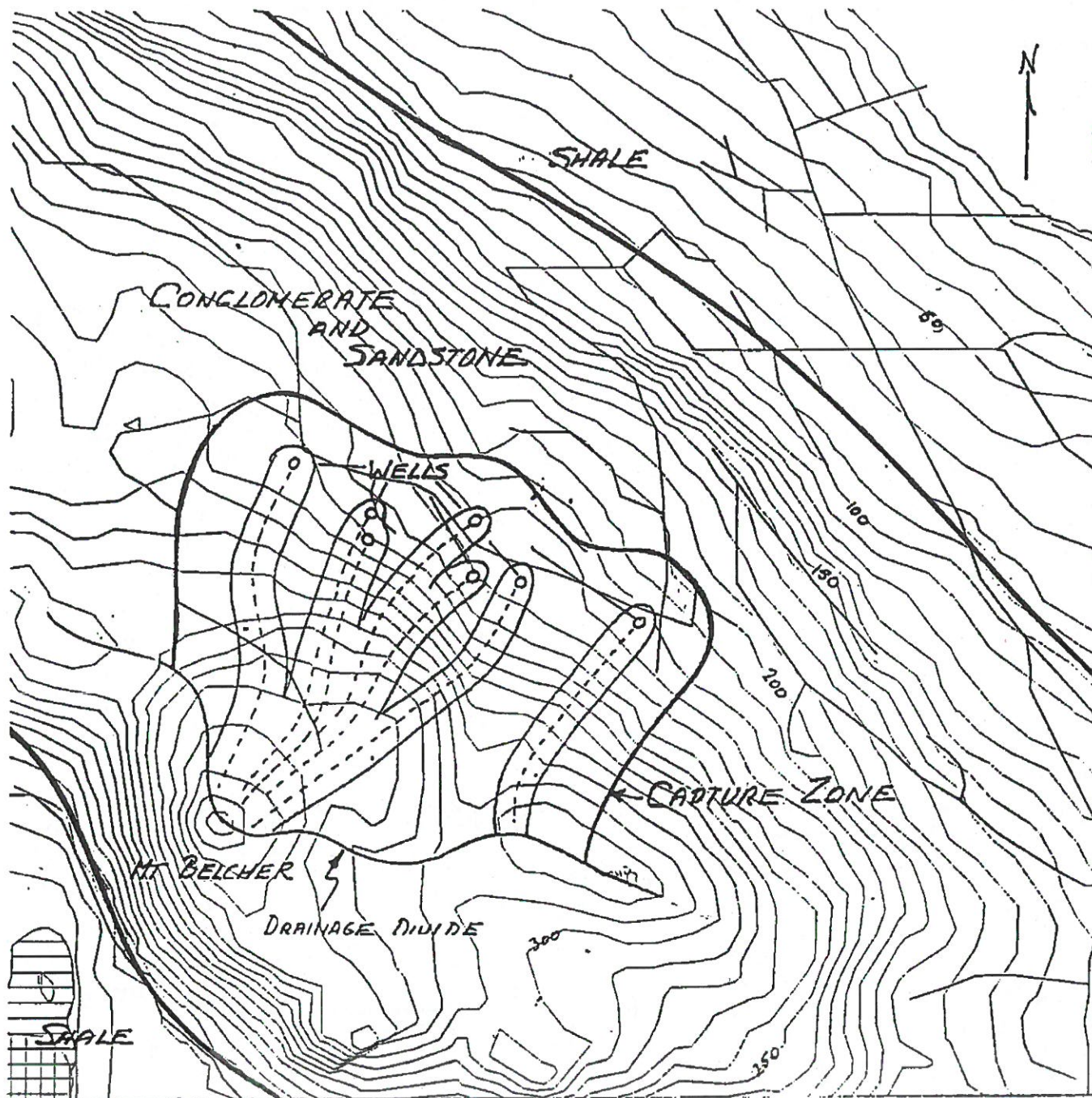


FIGURE 20
MT. BELCHER
CAPTURE ZONE
SCALE 1:10,000

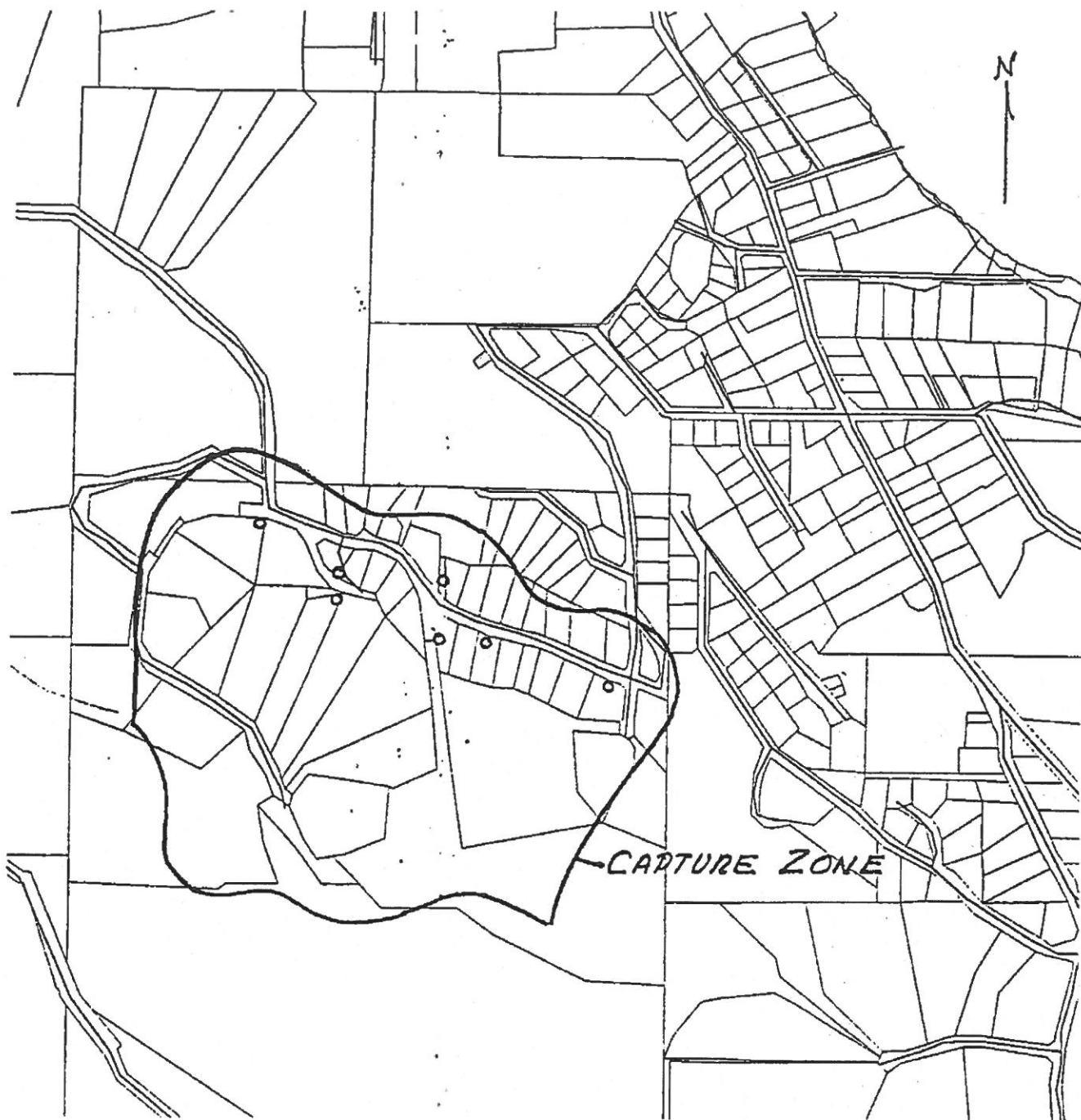


FIGURE 21
MT. BELCHER
CAPTURE ZONE
SCALE 1:10,000

5.0 CONCLUSIONS

The results of this study show capture zones for the respective community water supply systems which are conservative estimates. More precise definitions of these areas would require the inclusion of pump test data and most importantly the data from programs of well system and aquifer monitoring which would include the metering of pumping rates and the periodic measuring of water table elevations. These would encompass both the wells of the respective systems and any other wells within the capture zones.

6.0 RECOMMENDATIONS

5.1 Restrict the level of any contaminant producing activities within the capture zones. Septic systems may be significant sources of contaminants.

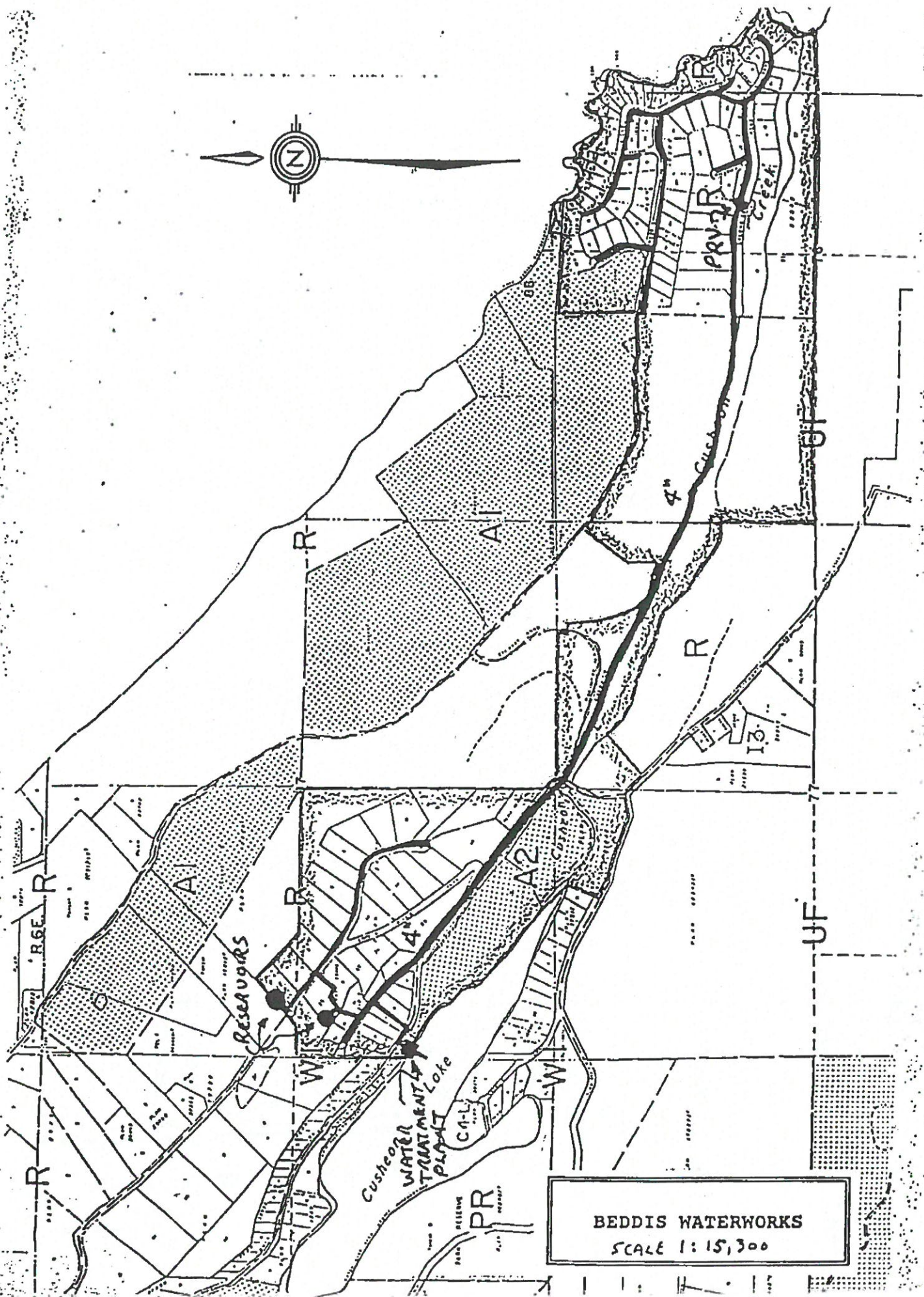
5.2 The requirements of any major proposed development within a capture zone should include a study sufficient to determine the possible effects of the development on the local aquifer.

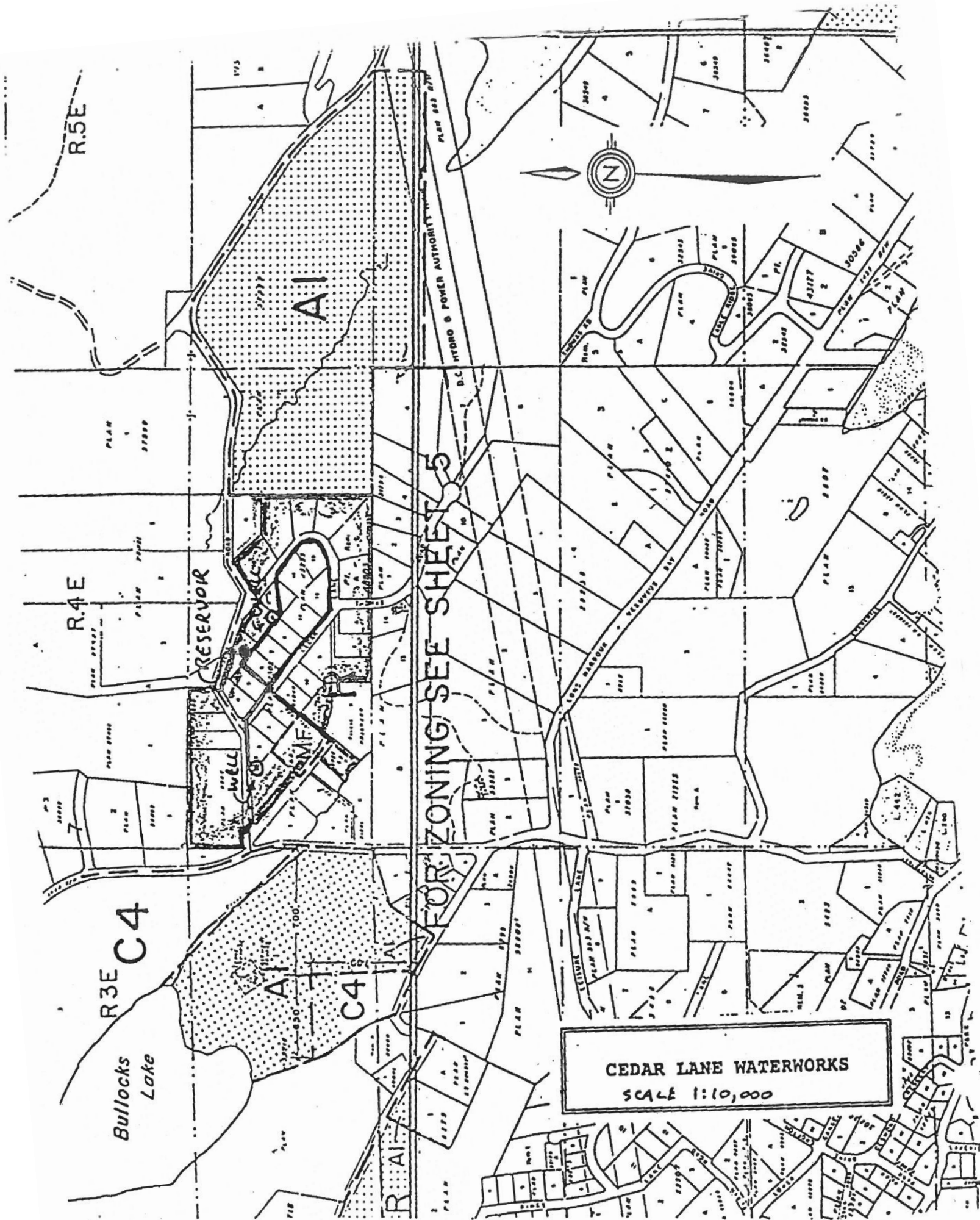


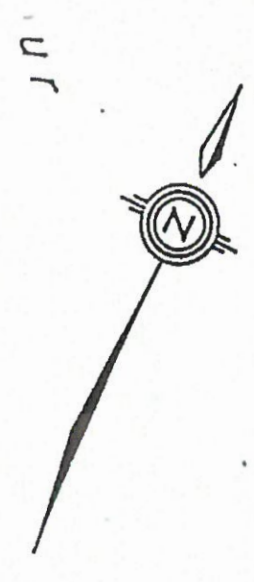
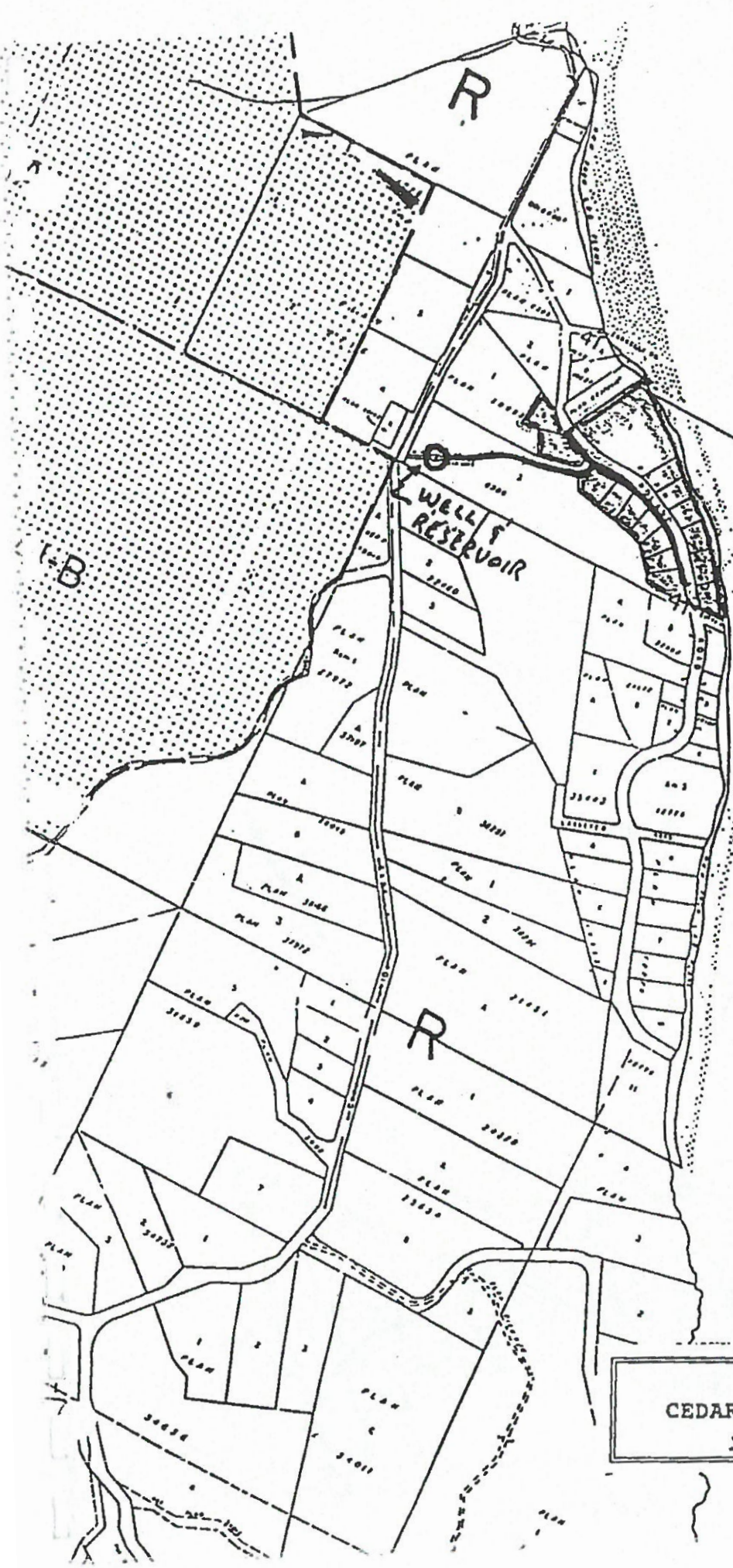
Robert Potter P.Eng
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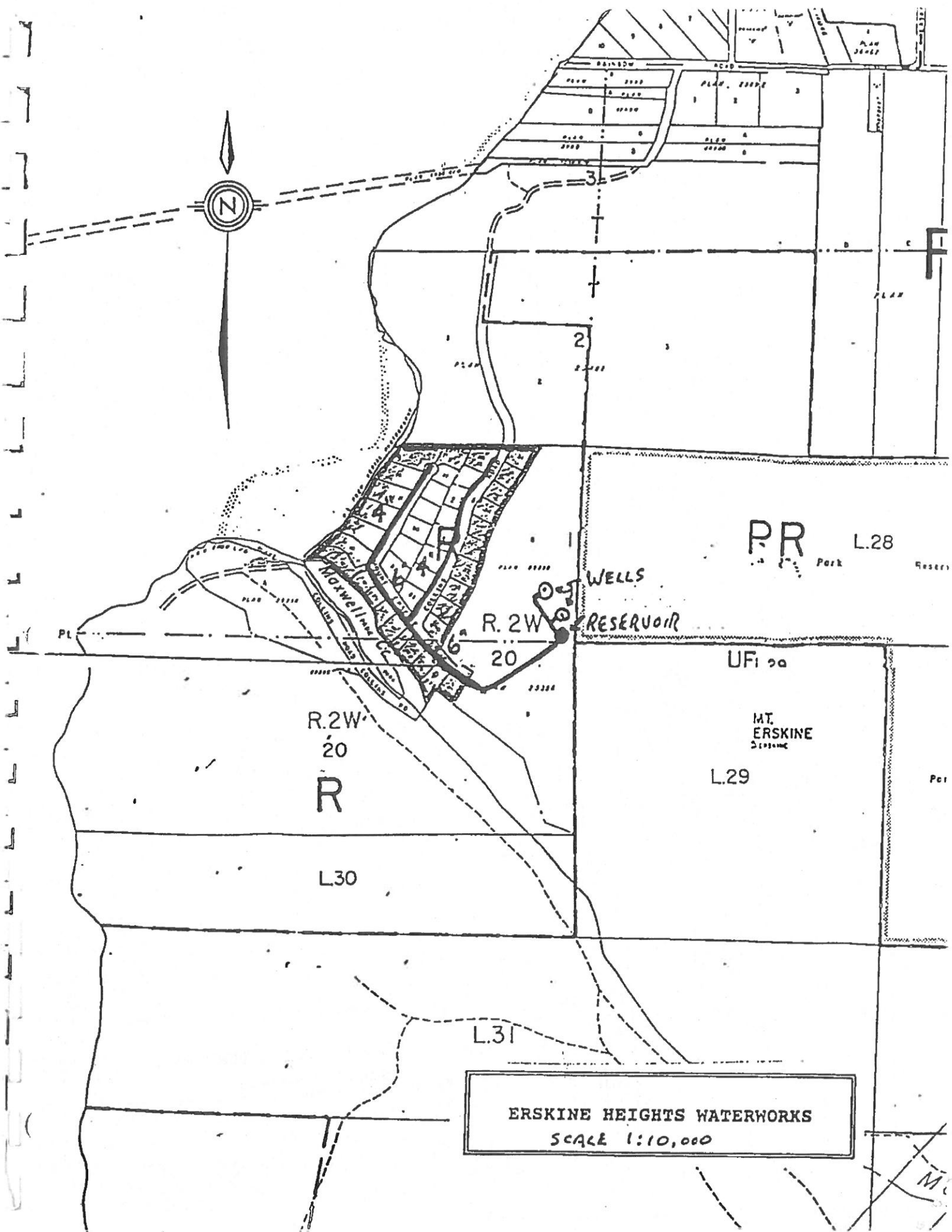




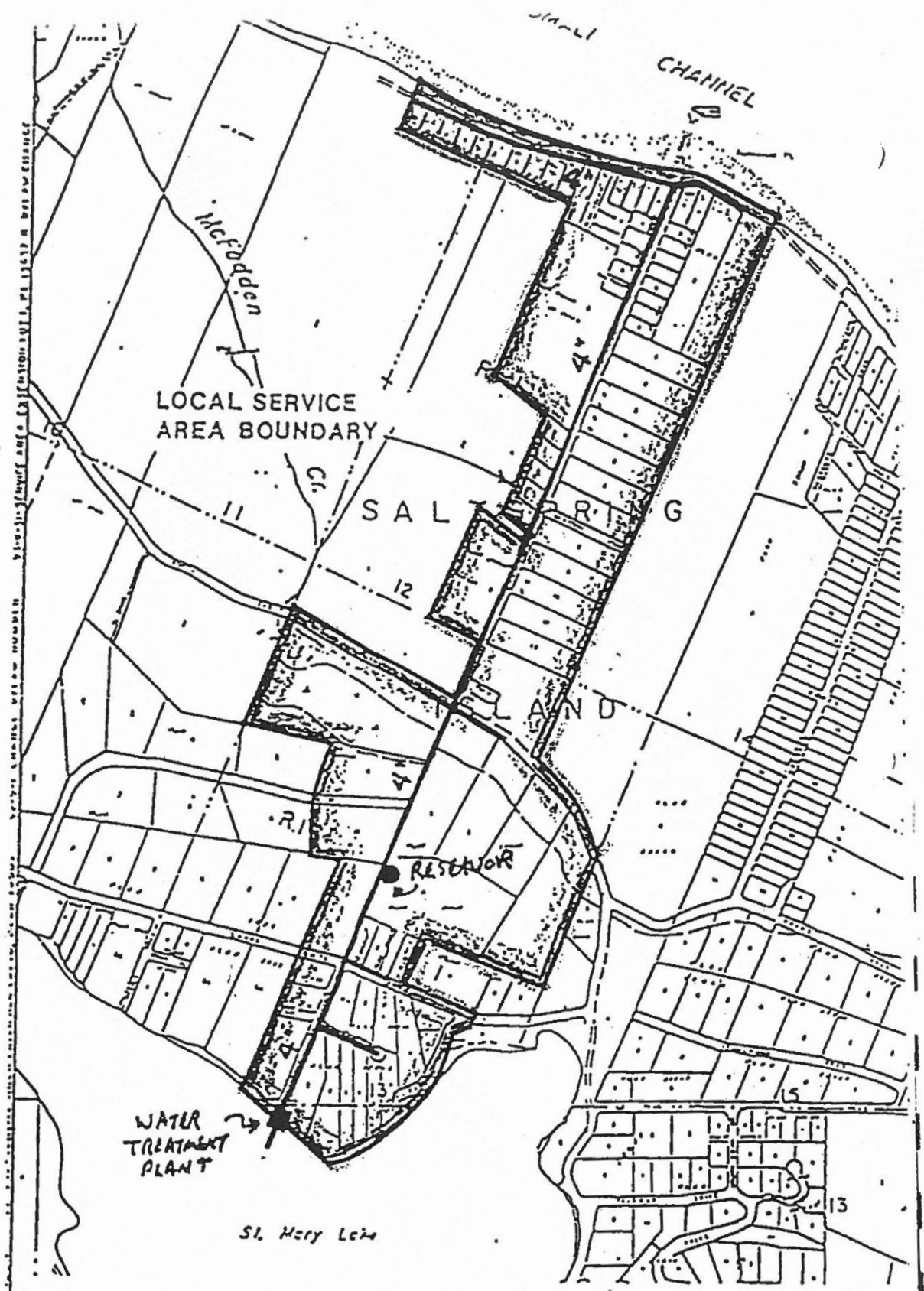
Fulford

Hobbold

CEDARS OF TUAM WATERWORKS
SCALE 1:10,000



ERSKINE HEIGHTS WATERWORKS
SCALE 1:10,000



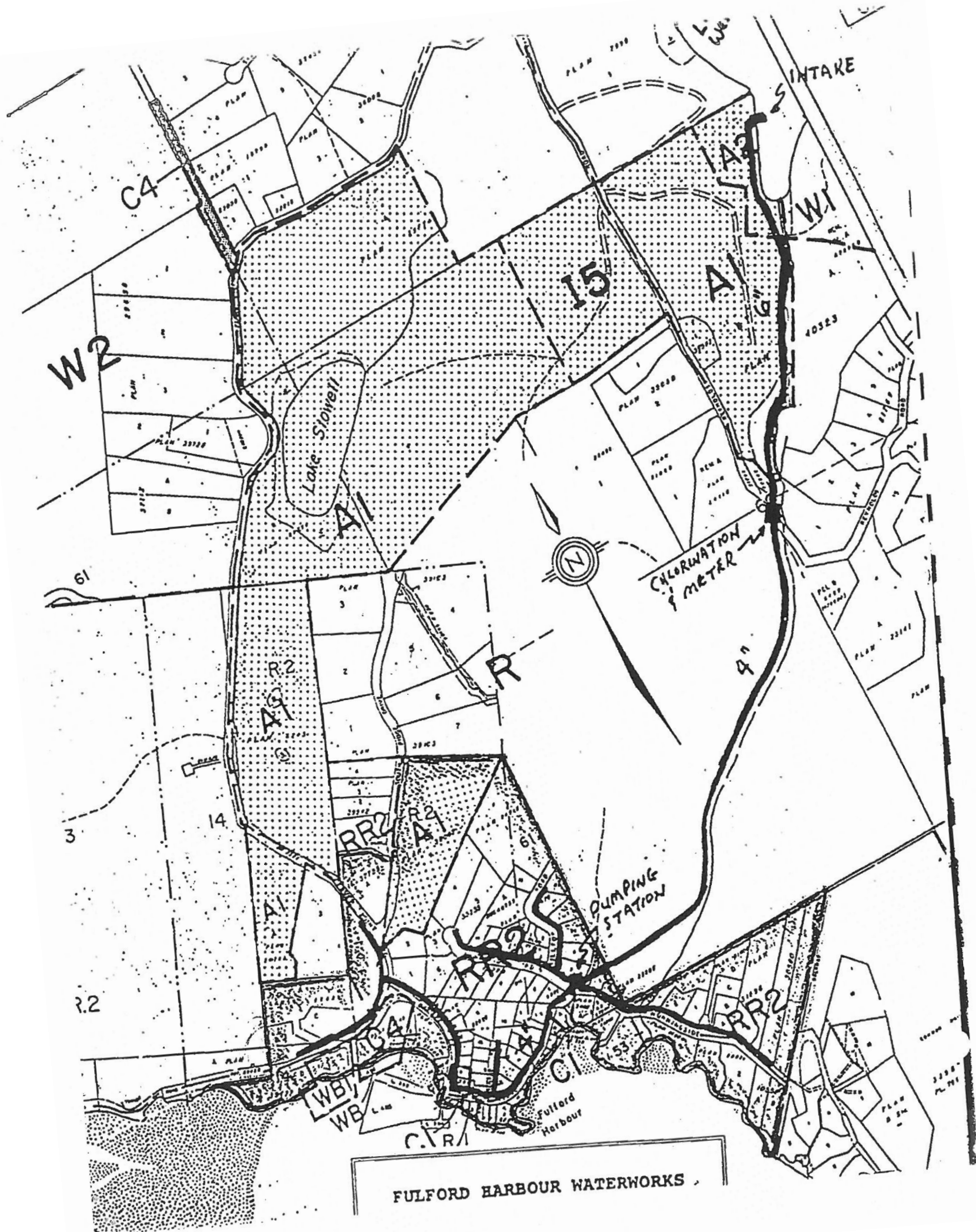
SCHEDULE "A" TO BYLAW 2187

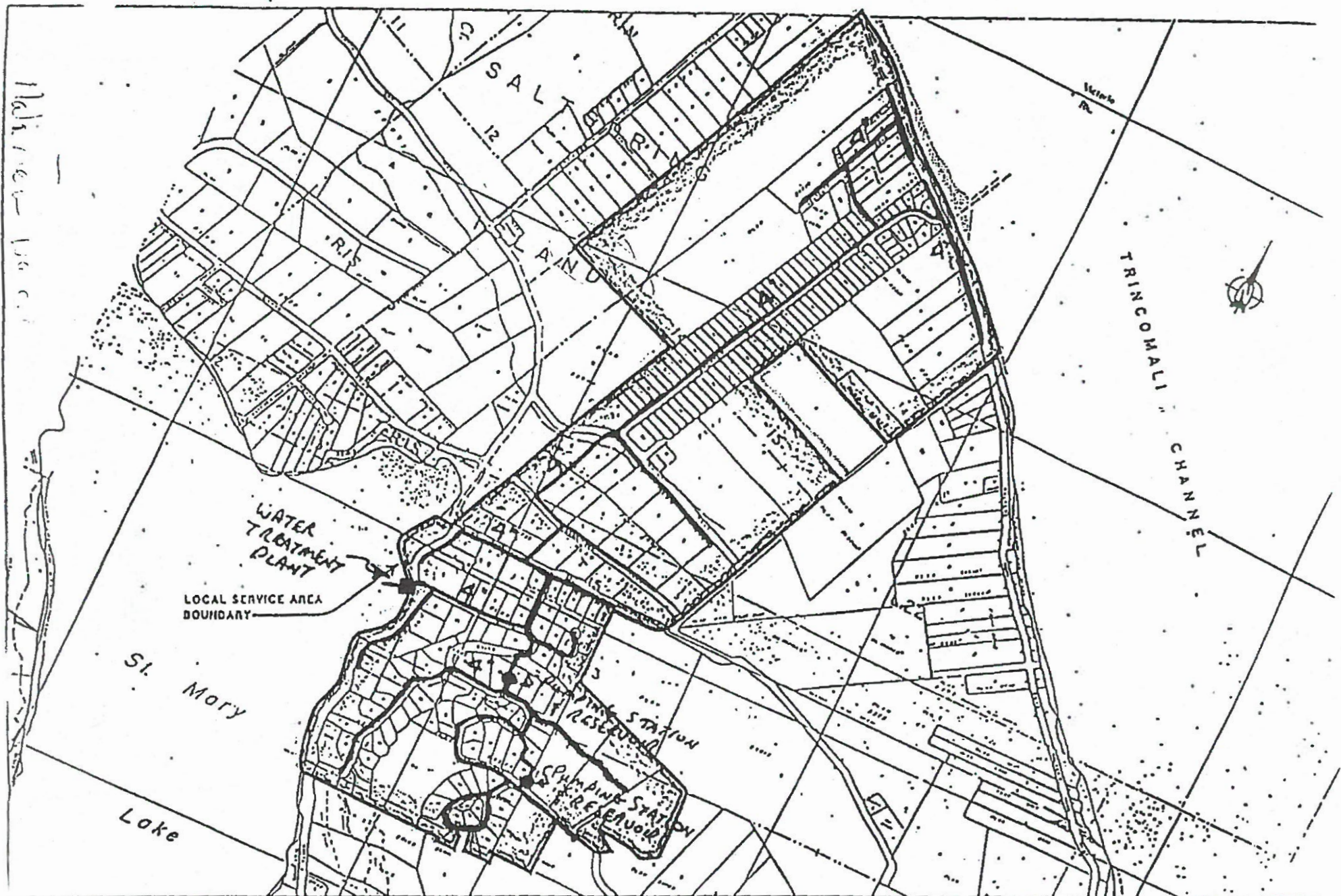
FERNWOOD WATER SUPPLY

LOCAL SERVICE ESTABLISHMENT BYLAW NO. 1, 1989



SCALE 1:12,000





CAPITAL REGIONAL DISTRICT ENGINEER			
DATE	BY	REVISION	REMARKS
1951	J. L.	1	INITIALS
1951	J. L.	2	INITIALS
1951	J. L.	3	INITIALS
1951	J. L.	4	INITIALS
1951	J. L.	5	INITIALS
1951	J. L.	6	INITIALS
1951	J. L.	7	INITIALS
1951	J. L.	8	INITIALS
1951	J. L.	9	INITIALS
1951	J. L.	10	INITIALS
1951	J. L.	11	INITIALS
1951	J. L.	12	INITIALS
1951	J. L.	13	INITIALS
1951	J. L.	14	INITIALS
1951	J. L.	15	INITIALS
1951	J. L.	16	INITIALS
1951	J. L.	17	INITIALS
1951	J. L.	18	INITIALS
1951	J. L.	19	INITIALS
1951	J. L.	20	INITIALS
1951	J. L.	21	INITIALS
1951	J. L.	22	INITIALS
1951	J. L.	23	INITIALS
1951	J. L.	24	INITIALS
1951	J. L.	25	INITIALS
1951	J. L.	26	INITIALS
1951	J. L.	27	INITIALS
1951	J. L.	28	INITIALS
1951	J. L.	29	INITIALS
1951	J. L.	30	INITIALS
1951	J. L.	31	INITIALS
1951	J. L.	32	INITIALS
1951	J. L.	33	INITIALS
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1951	J. L.	36	INITIALS
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1951	J. L.	97	INITIALS
1951	J. L.	98	INITIALS
1951	J. L.	99	INITIALS
1951	J. L.	100	INITIALS

ATHOL

PENINSULA

Lang Harbour

Welbury Bay

RESERVOIR

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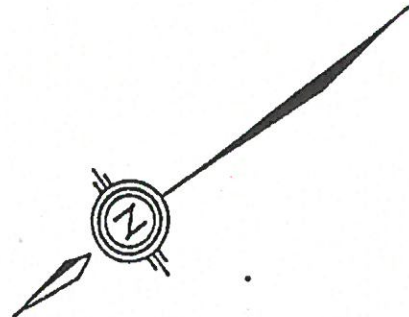
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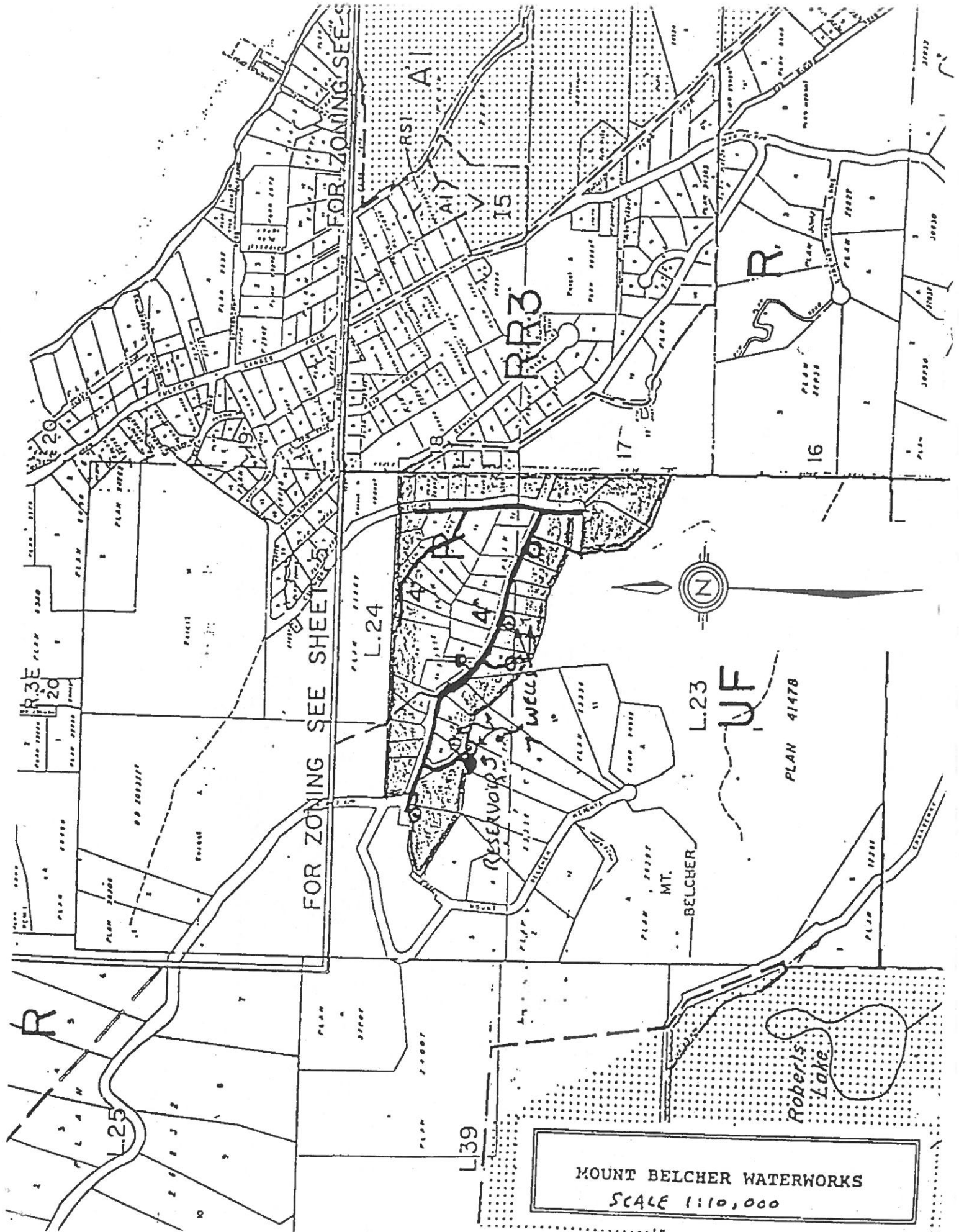
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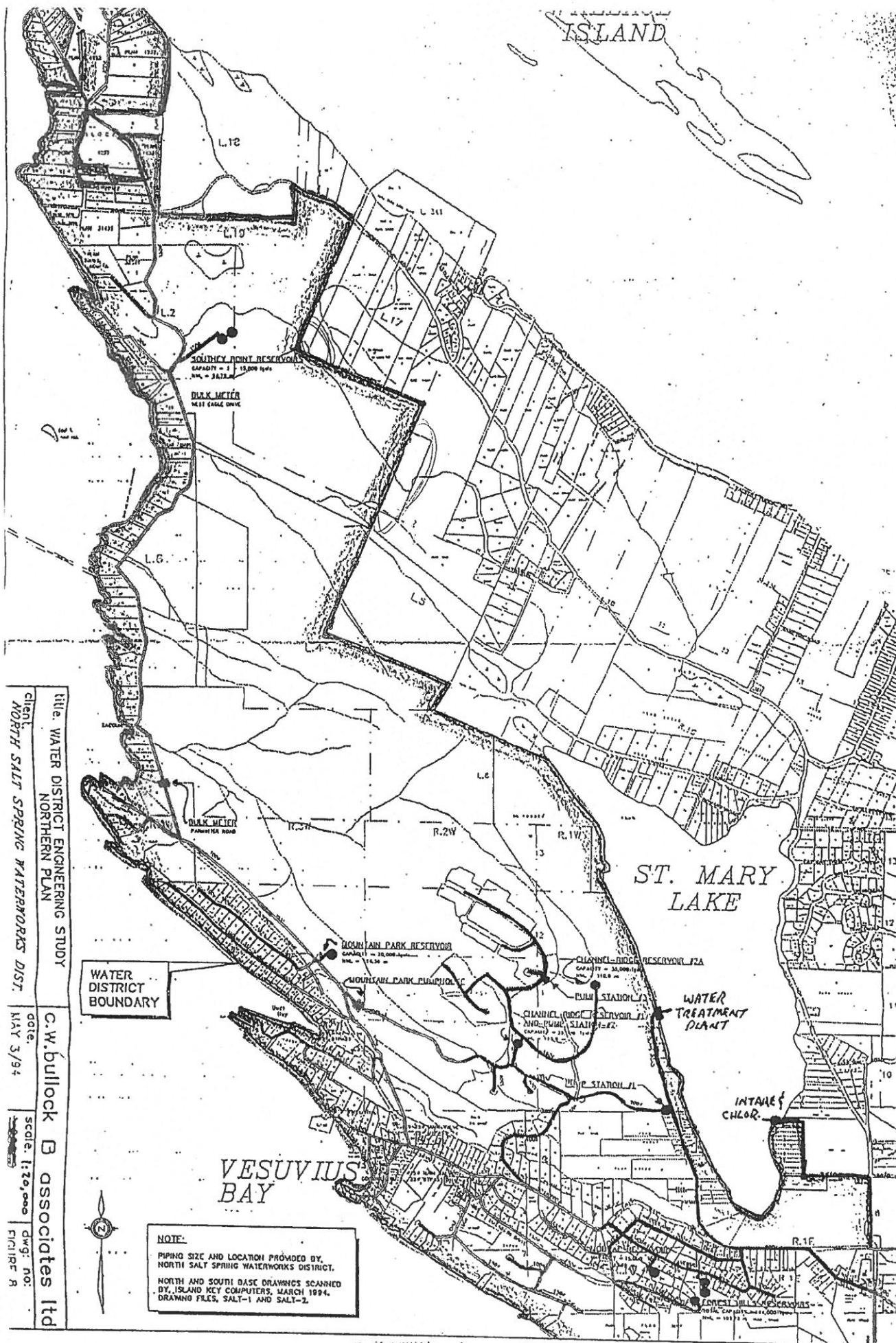
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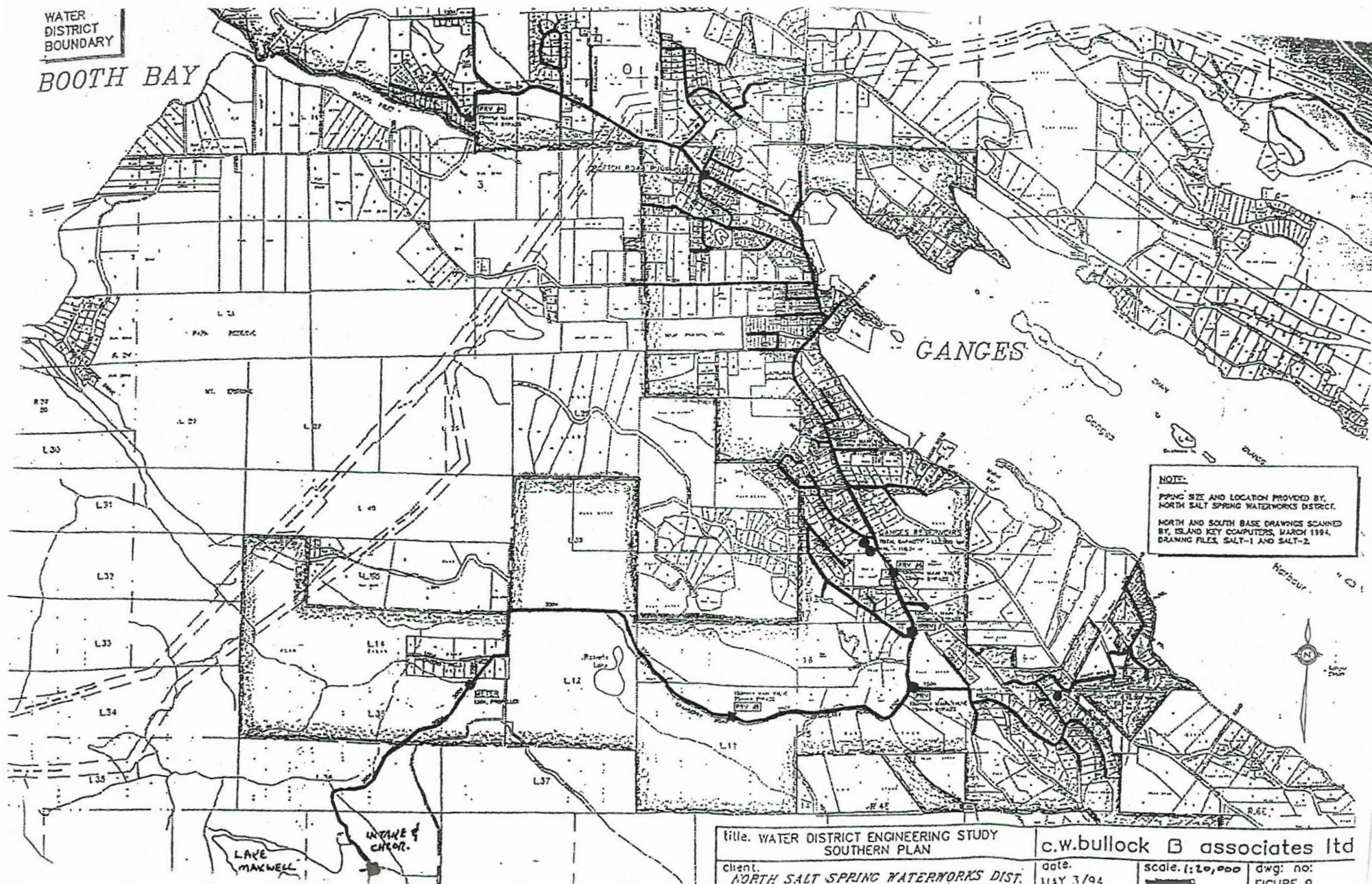
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title. WATER DISTRICT ENGINEERING STUDY
SOUTHERN PLAN

client. NORTH SALT SPRING WATERWORKS DIST.

c.w.bullock & associates ltd

date. MAY 3/94

scale. 1:20,000

dwg. no: FIGURE 9

