5.0 GEOMORPHOLOGY, TOPOGRAPHY AND DRAINAGE

Topography is not only one of the main controls on surface water runoff but also has a significant influence on water table position; the water table configuration is a subdued reflection of the surface topography. The influence of topography is more pronounced in hilly and mountainous terrain with high relief, however topography can be an important consideration is areas of low relief. Direct groundwater discharge occurs where the water table intersect the ground surface (natural and man-made such as in quarries) or indirectly via evapotranspiration where the water table is close to the ground surface.

The Garfield North area is located on a dissected plateau-like surface known as the Nillumbik Terrain bounded by the Eastern Uplands to the north and the Gippsland Plan to the south. The Nillumbic Terrain extends from the eastern suburbs of Melbourne as far east as Bairnsdale. Dendritic patterns of narrow ridges and valleys are typical of the region and characterize much of the deeply dissected landscape on either side of the Great Divide. South of the Great Divide the streams have steeper gradients and deeper valleys, and as they approach the Eastern Plain, having narrower alluviated valleys than those in the north. The southern boundary of the Eastern Uplands is the southern edge of an uneven bench-like platform known as the Nillumbik Terrain, which can be traced bordering the Eastern Plain from near Orbost to the eastern suburbs of Melbourne. Local stream tend to have relatively steep gradients and deep valleys, and as they approach the Eastern Plain, narrow alluviated valleys.

The Eastern Plains are mostly of low relief, ranging from undulating rises to almost level plains. The surficial sediments are mostly alluvial and range in age from Quaternary to Recent. These mainly comprise sediments derived from the Eastern Uplands (EU) to the north. The youngest sediments are the flood plains, swamps and morasses associated with the present rivers and streams. The swamp and lagoonal deposits were drained after European settlement.

The topography in the Garfield North and surrounding area is shown as Digital Elevation Model (derived from 10 m contour data) in Figure 5.1 and illustrated as a relief map in Figure 5.2.

The drainage pattern in the Garfield North area is shown in Figure 5.3. The density of streams in the hilly terrain is significantly higher than that on the adjoining Eastern Plain. WA1438 is located within the Bunyip River Catchment.

The topography across WA1438 and immediate adjoining land was mapped from one metre elevation contour provided by Hanson. [The Hanson digital set contained a large number of data points that plotted as “bulleyes’ on contour maps and spikes/peaks on digital elevation models. These points were removed from the data set by JLCS.] Elevations in areas not covered by the Hanson data were obtained from 10 m contours, and spot heights on DSE online maps.

WA1438 is located towards at the eastern end of a general NW-SE aligned ridge of outcropping granite. The site is surrounded by the shallow valleys of Hamilton Creek (west), Cannibal Creek (south) and Two Mile Creek West (north).

The main topographic features at WA1438 are two ridges. The main ridge is aligned approximately west-east and includes two local topographic highs, one on the western boundary of the site and a central "high" which attain elevation in excess of 150 and 140 m AHD, respectively (Figure 5.4). This ridge bifurcates into two lower spurs towards the northeastern corner of site. The secondary ridge trends in an approximate north-south direction off the main ridge. The ridges have been eroded forming a number of small gully-like topographic features.

The site elevation ranges from about 80 m AHD in the northeast corner of the WA1438; 90 m AHD in southwestern corner; 90-100 m AHD along the southeastern boundary; 100 m AHD along the northern boundary along the base of the Deep Creek tributary near the northwestern corner of WA 1438 up to more than 120 m AHD on the hill in the eastern portion of the site.

The site topography is illustrated in the DEM of the quarry and by "filled" contours in Figures 5.3 and 5.4, respectively. North-south and west-east topographic profiles through WA1438 are shown in Figure 5.5.

The general runoff directions across WA1438 are indicated by the terrain slope vectors plotted on a site contour map in Figure 5.6: Runoff to the north of the main ridge flows into a minor unnamed tributary of Two Mile Creek West. Runoff to the south of the main ridge and east the secondary ridge flows either directly or via two gullies into a second unnamed tributary of Two Mile Creek West. Runoff from the southwestern corner of the sites flows into Cannibal Creek.

Both Two Mile Creek West and Cannibal Creek flow in general easterly directions into the Bunyip River. The Bunyip River flows south to the confluence with the Tarago River. South of the Nar Nar Goon – Longwarry Road (east of the Bunyip township) the Bunyip River has been altered into a man-made channel as part of extensive Koo Wee Rup Swamp drainage works which were commenced in the late 1880s. Man-made realignment of creeks and constructed drain are evident to the north of the Princess Highway on the Bunyip River system alluvial flats. Part of the Two Mile Creek West system also appears to have been channelized as indicated by unnaturally straight stream segments.

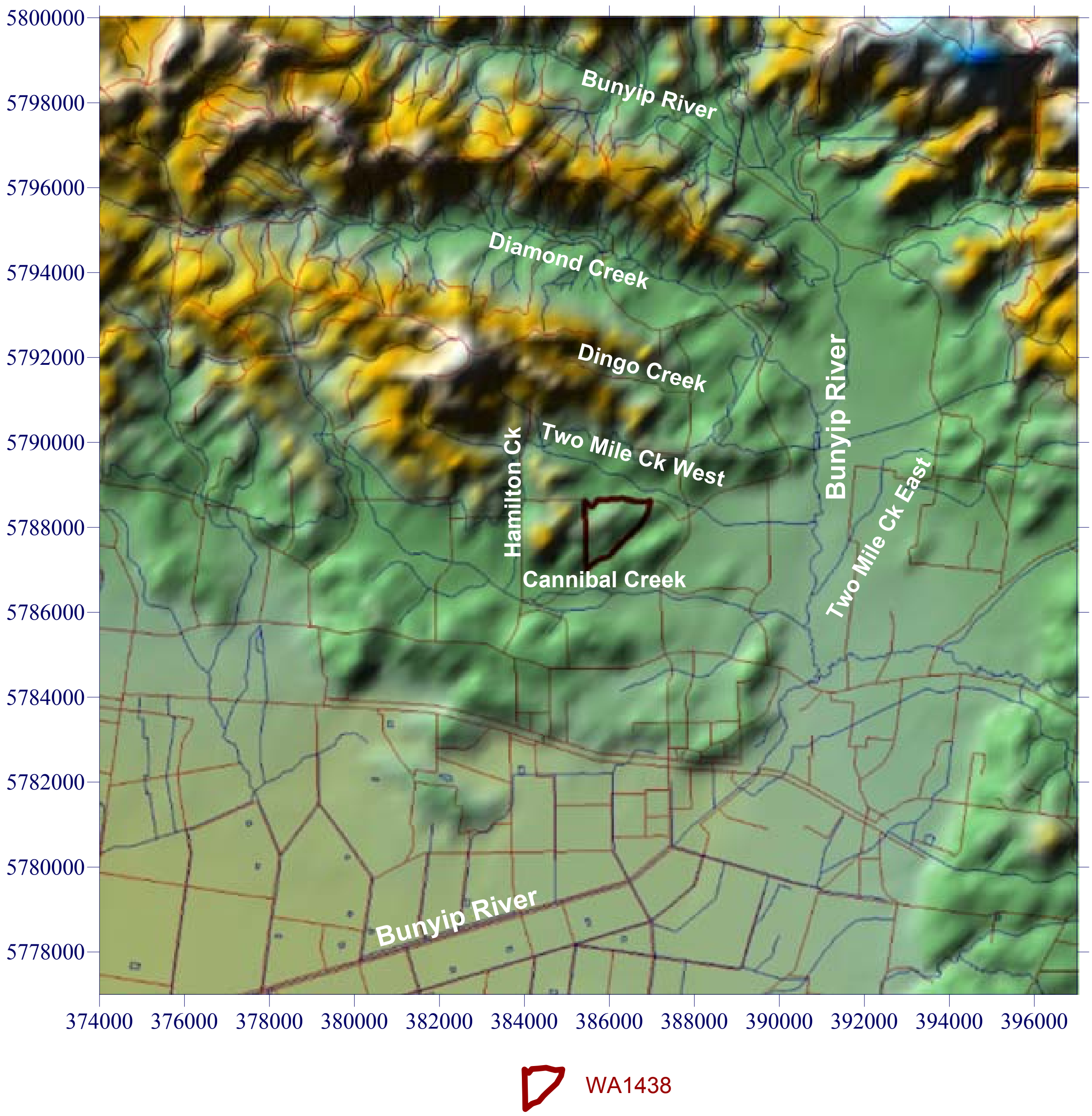


FIGURE 5.1 Garfield North Regional Topographic Relief Map

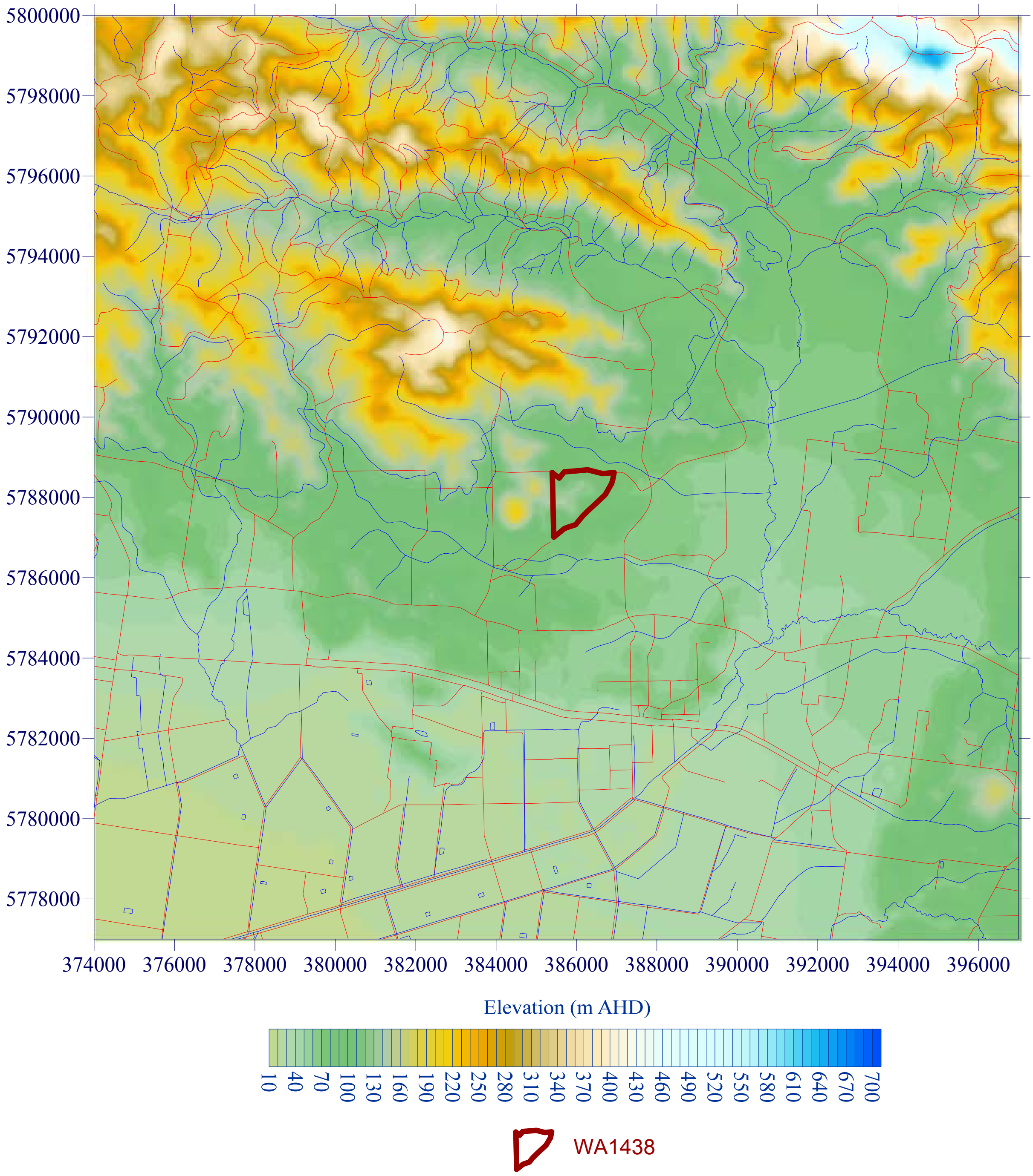


FIGURE 5.2 Garfield North Regional Topography and Drainage Pattern

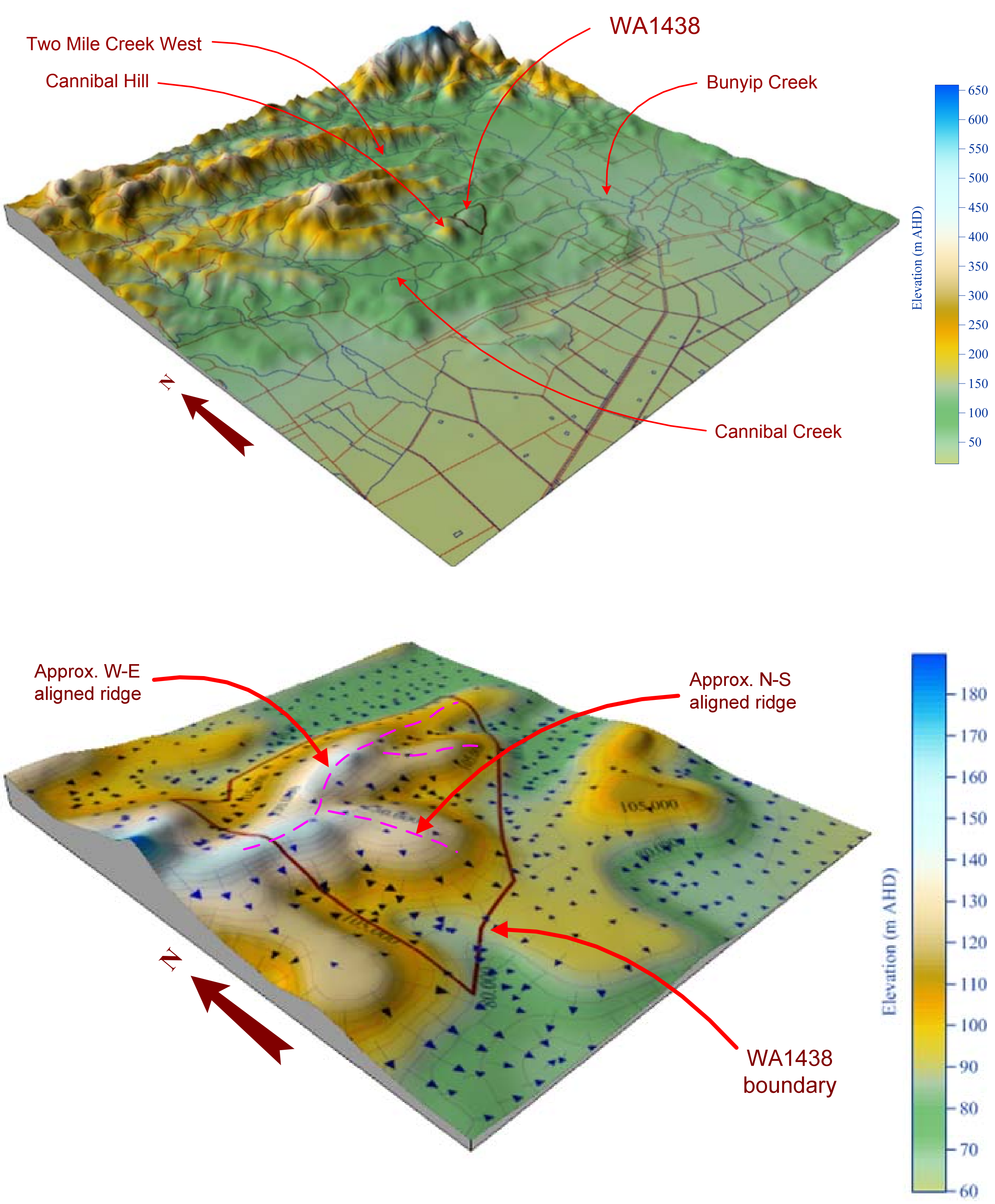


FIGURE 5.3 Garfield North Digital Elevation Models; A) Regional, and B) Local

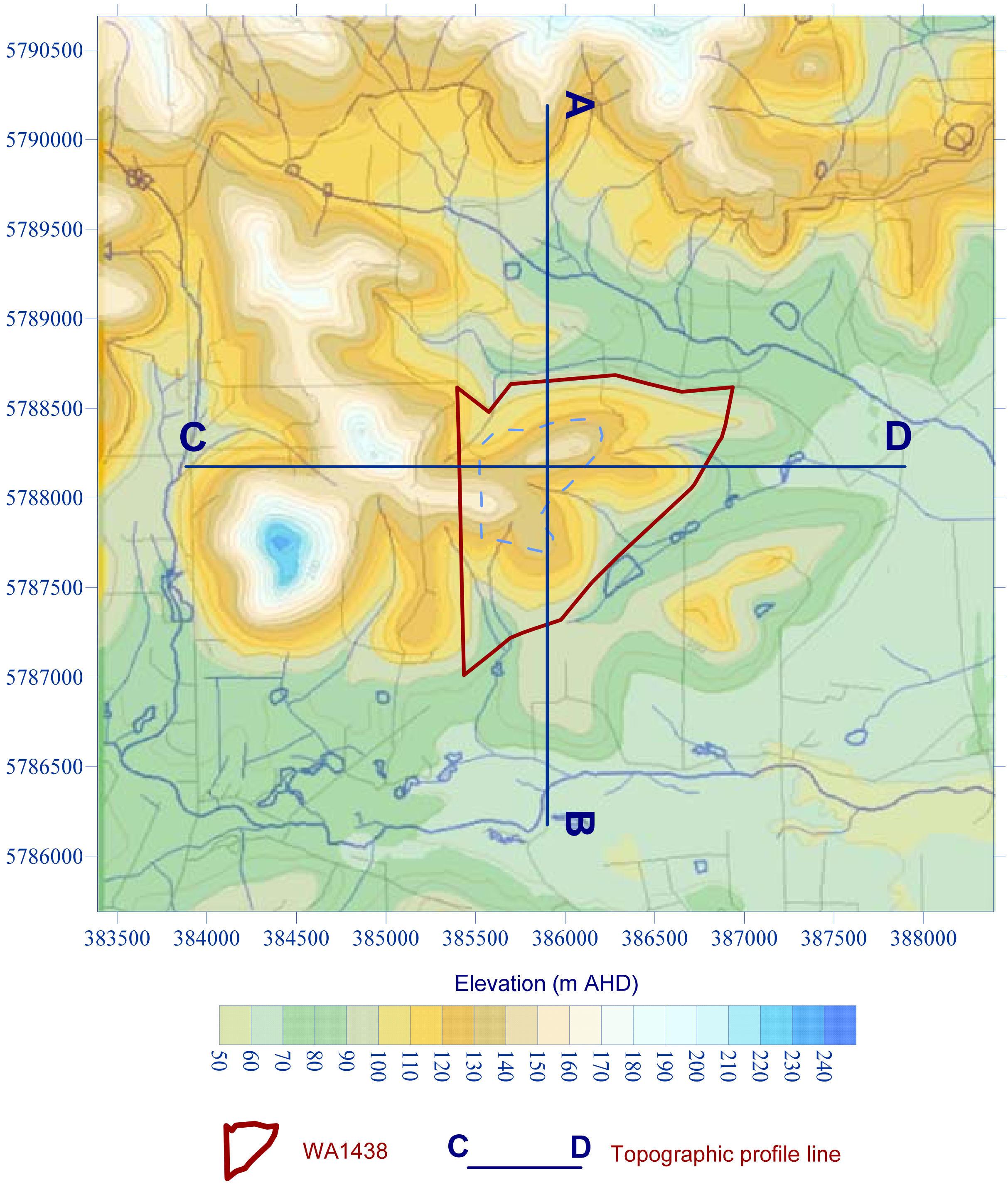


FIGURE 5.4 Garfield North Local Area Topography

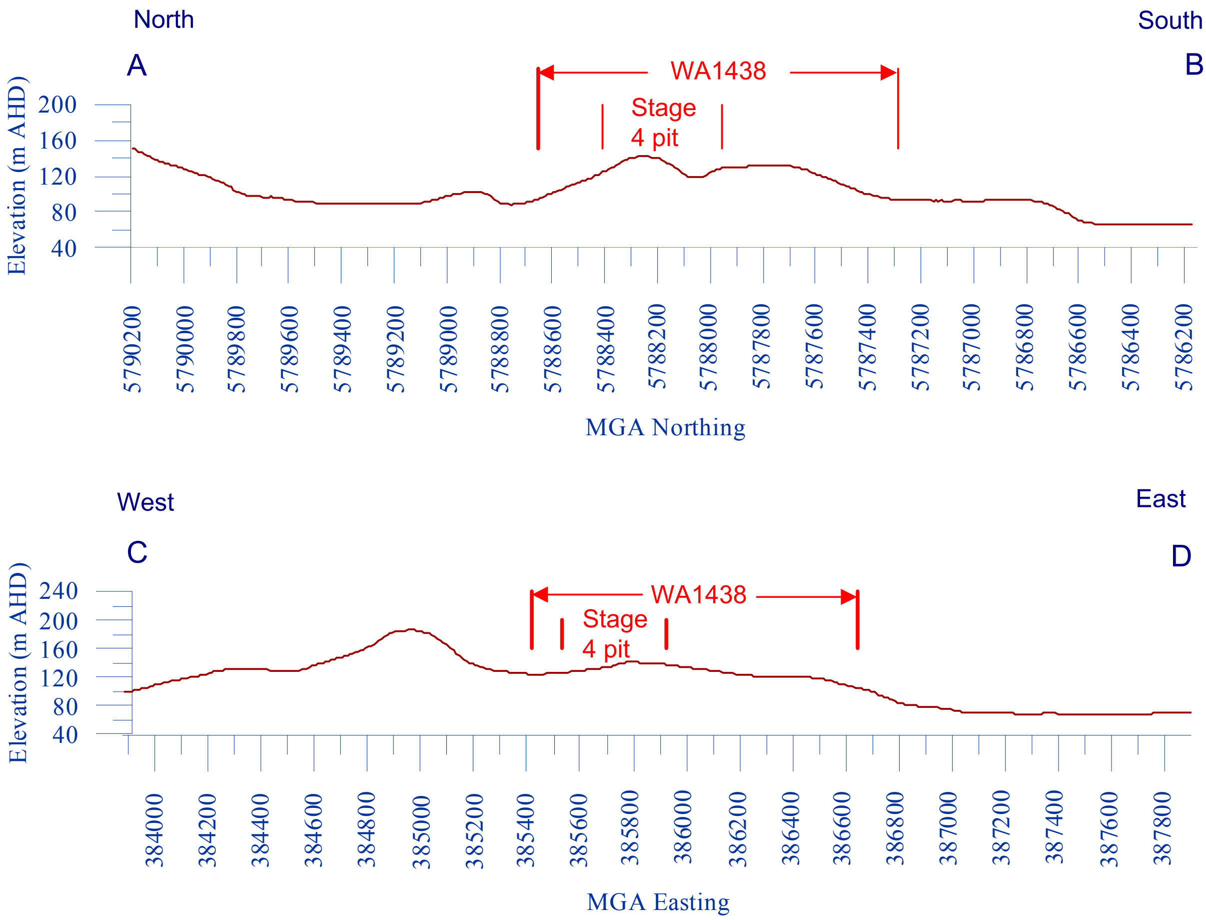


FIGURE 5.5 Garfield North Topographic Profiles Through WA1438

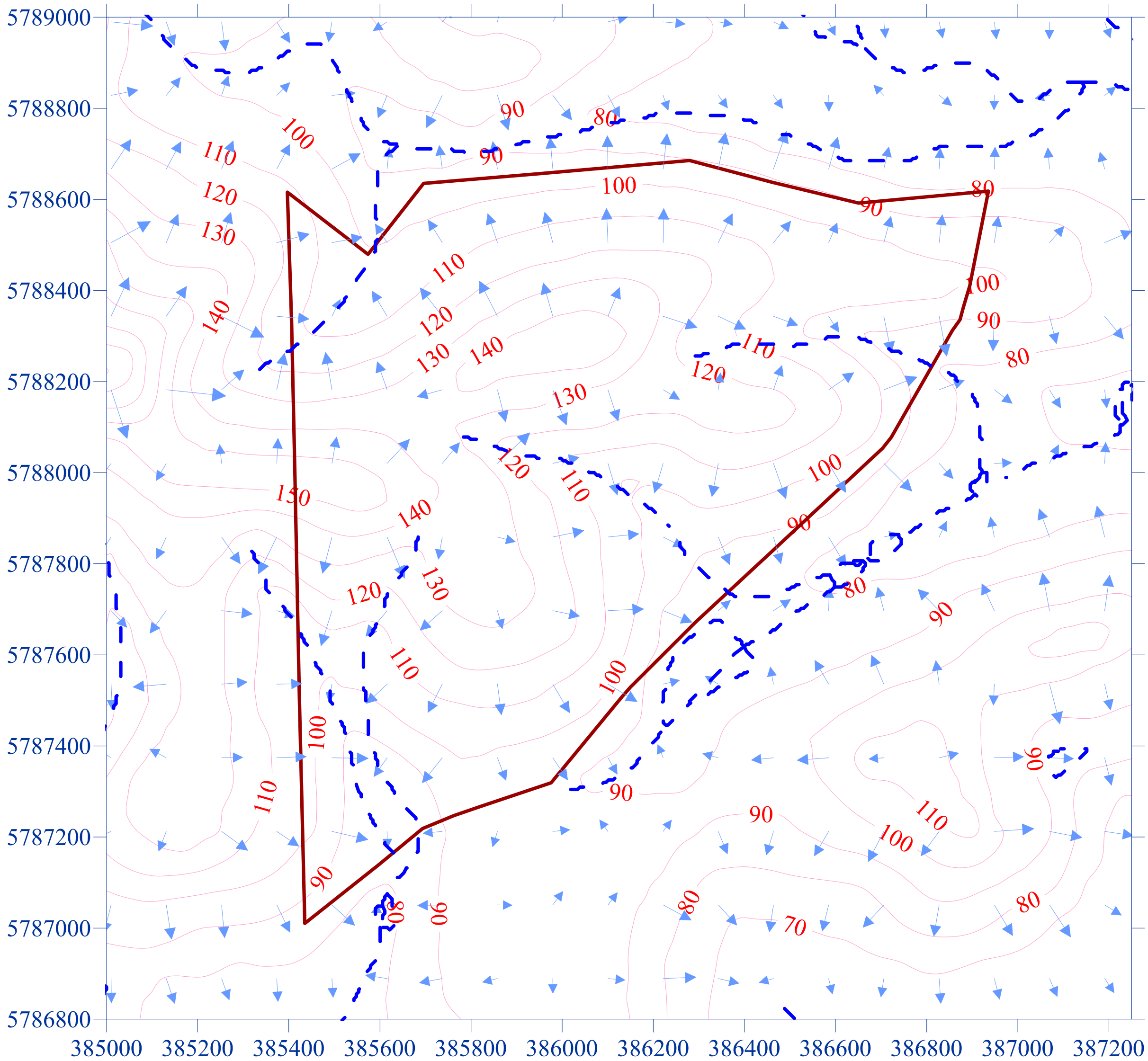


FIGURE 5.6 WA1438 Drainage Lines and Terrain Slope Vectors

6.0 HYDROGEOLOGY

The geological history of an area controls the number and type of aquifers, their lateral and vertical extent, and configuration (depth, outcrop pattern), hydraulic properties and degree of interconnection. Surface/outcrop geology controls the recharge/discharge regime of aquifer systems whilst subsurface geology controls the distribution and flow of groundwater. Near surface geology can also control development of soil waterlogged condition or perched water tables above the main water table.

6.1 GEOLOGICAL SETTING

WA1438 is located in the foothills of the Eastern Highlands (uplands) along the eastern margin of the Western Port Basin (sedimentary basin). The regional tectonic setting and outcrop geology is shown in Figure 6.1. The outcrop geology across WA1438 is mapped as Tynong Granite (Figure 6.2). Outcropping Tynong Granite is mapped over a large area on the 1:250,000 Western Port-Warragul (Map 51) and Ringwood-Healesville (Map 42) map sheets prepared as part of the DPI Seamless Geology Project (Welch, et al., 2011).

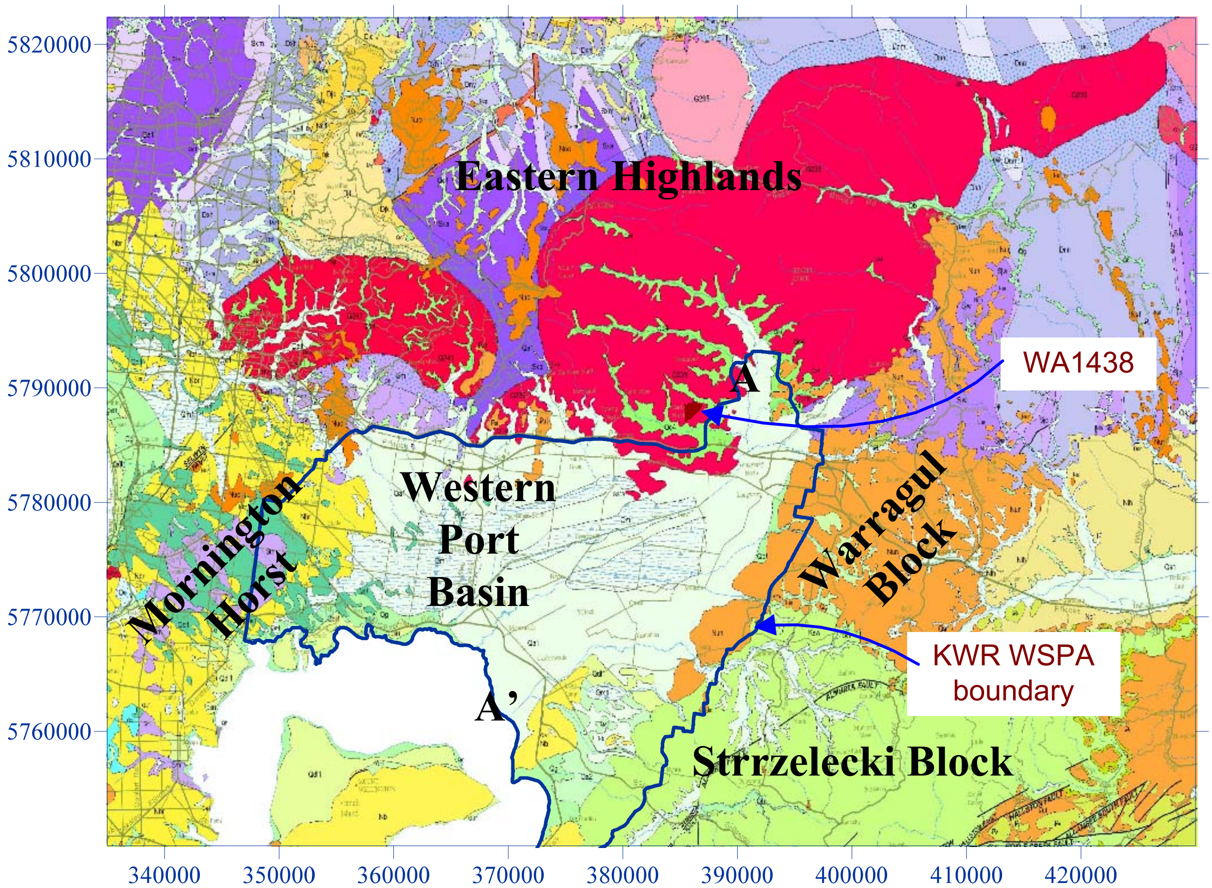


FIGURE 6.1 Regional Physiographic Setting and Outcrop Geology

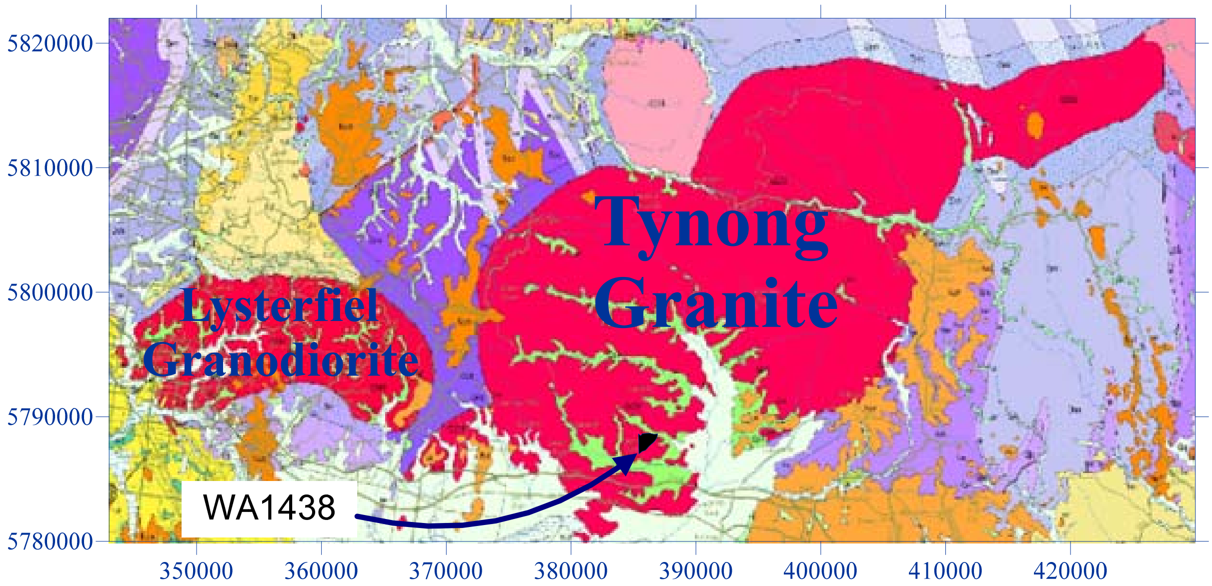


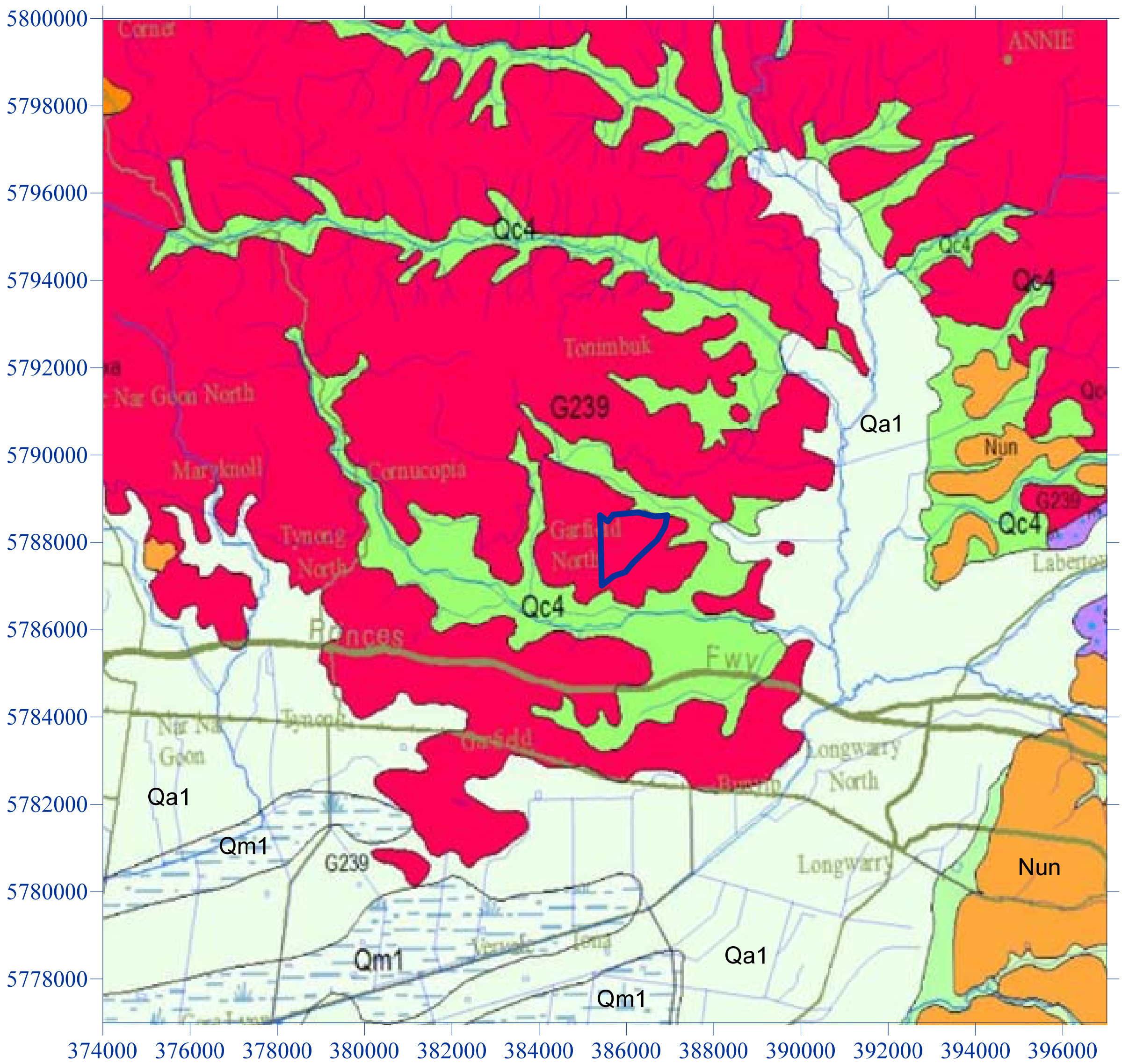
FIGURE 6.2 Mapped Extent of the Tynong Granite Outcrop (after Welsh, et al., 2011)

The local outcrop geology in the Garfield North and at WA1438 and immediate surrounding area are shown in Figures 6.3 and 6.4, respectively; both maps were (digitally) extracted from the 1:250,000 scale Western Port-Warragul Map Sheet. The site and immediate surrounding area geology is draped over a digital elevation model in Figure 6.5. The WA1438 "hilltop" is almost completed surrounded by colluvium (Qc4) derived from the granitic hills. Further to the east, the granite is overlain by alluvium deposited by streams of the Bunyip River system. Site investigation work by ATC Williams indicates that the granite at WA1438 is varyingly weathered.

Three rock types have been mapped in the Garfield North area namely, 1) Tynong Granite (local bedrock), 2) colluvium derived from the granitic parent rock, and 3) Quaternary alluvium (east of WA1438 along reaches of the Bunyip River system).

6.2 TYNONG GRANITE

The Tynong Granite is predominantly a fractured rock type aquifer. Fractured rock aquifers store and transmit water through joints and fractures in an otherwise impervious rock mass and exhibit hydraulic characteristics which are dependent on the nature (number, size and extent) of discontinuities in the rock mass and their degree of interconnection. The "fracture voids" are usually poorly interconnected. The storage capacity and ability of the fractured rock aquifers to act as conduits for the passage of groundwater is dependent on the frequency, openness and degree of interconnection of joints and fractures. Fractures may persist at depth, however, permeability generally decreases with depth as the frequency of fractures decreases and rock discontinuities tend to close because of the weight of overlying rock.



	Qc4	Granite derived colluvium	
Quaternary	Qa1	Unnamed stream and flood plain alluvium	Silt, clay, sandy silty clay, sand
	Qm1	Unnamed swamp and lake deposits	Clay, silt, peat, sandy silty clay
Tertiary	Nun	Neerim Volcanic Group	Basalt, pyroclastics, plugs
Devonian	G239	Tynong Granite	Granite
Silurian	Sjw	Whitelaw Siltstone	Massive siltstone, mudstone, minor sandstone, shale and conglomerate

WA1438

FIGURE 6.3 Outcrop Geology, Garfield North Area (after Welsh, et al., 2011)

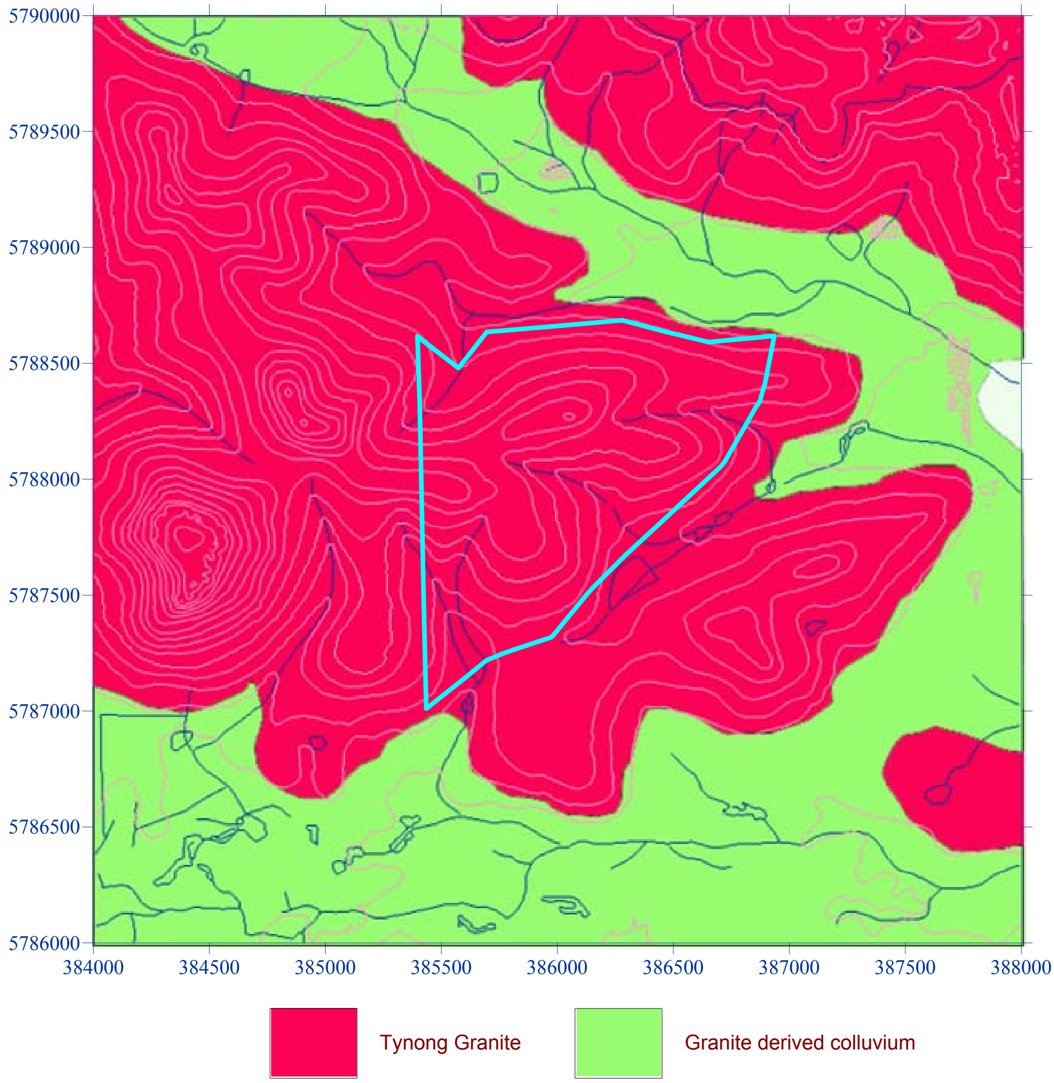


FIGURE 6.4 WA1438 Local Outcrop Geology (redrawn after Welsh, et al., 2011)

The upper surface of the Tynong Granite is varyingly weathered. The weathering has resulted in the alteration of the granite to clay minerals which act as a very low permeability porous medium type aquifer or aquitard which inhibit the movement of water.

Groundwater in the outcropping granite varies from unconfined to semi-unconfined depending on the hydraulic characteristics of the material above the water table. The hydraulic conductivity of the unit is generally very low with the unit often considered as “groundwater basement” in regional groundwater resource assessment. The relatively high density of streams area of outcropping Tynong Granite is consistent with low hydraulic conductivity rocks. The water table hydraulic gradient in the granite would be (correspondingly) very steep.

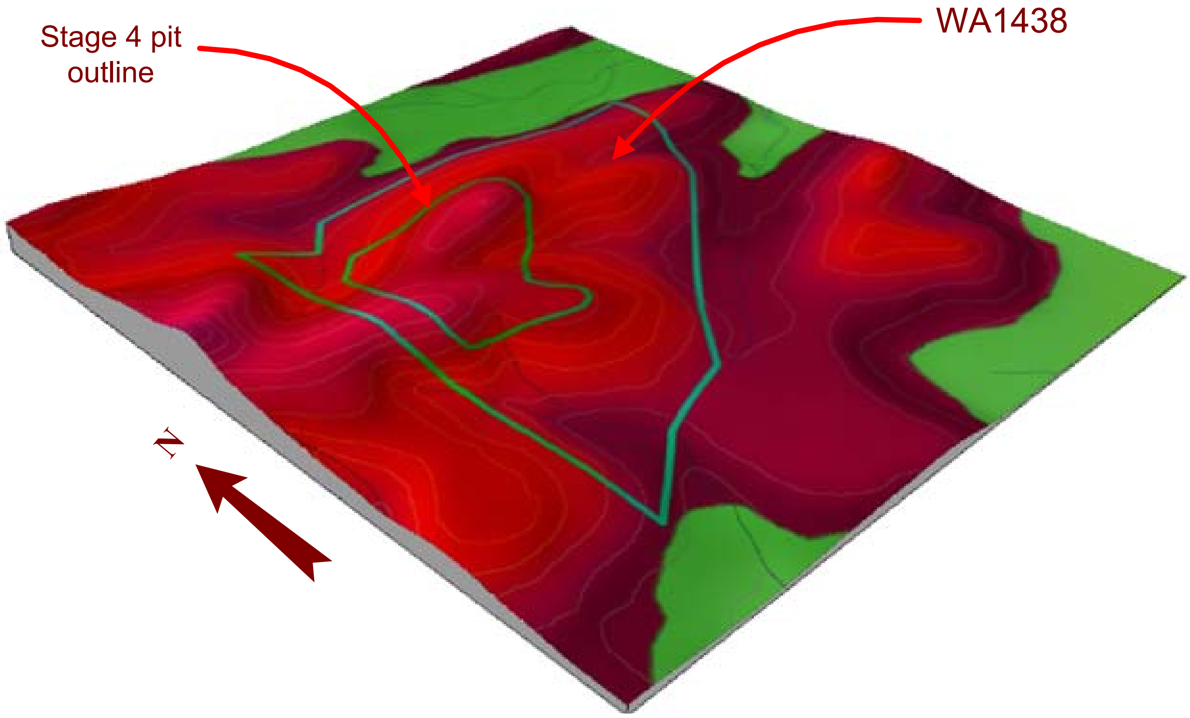


FIGURE 6.5 WA1438 Local Outcrop Geology Draped Over DEM

The water table beneath WA1438 is relatively shallow. The depth to the water table in the hilly Garfield North area is a function of the local topography and the hydraulic conductivity of the Granite bedrock. The water table is deeper under higher elevated areas (local hills) crests and ridges and shallower beneath valley floors which is typical for mountainous terrain where the water table follows the topographic relief in a subdued manner. If flow in the local creeks is permanent, the flow is sustained flow by groundwater discharge (baseflow). In these stream reaches, the water table must be above the stream stage (level of water in the streams). Water level monitoring at WA1438 indicates that the water table is shallow beneath local topographic highs. This observation indicates that the granite is relatively impermeable. If the granite is permeable the water table beneath the hills would be deep.

The results of borehole permeability testing, and the observed hydraulic response of the groundwater system to the 7-day pumping test and interpreted aquifer hydraulic parameters indicate the granite has very low permeability and is not a productive aquifer.

Recharge rates into the Tynong Granite aquifer are considered to be only a small percentage of local rainfall (less than 5 per cent) due to a combination of the steep topography in the hilly terrain and the weathering of the granite to clay minerals which inhibit infiltration.

The reported salinities of the groundwater in the Tynong Granite based on records in the GMS data base (September 2012 update) and from tests undertaken by ATC Williams (2009), was mostly less than 1,000 mg/L TDS (Table 6.1; Figure 6.6).

TABLE 6.1 Groundwater Salinity Garfield North Area Summary Details

Bore	MGA E	MGA N	Outcrop Geology	Depth (m bgl)	Sample (m bgl)		TDS (mg/L
					From	To	
53563	386927	5785779	Colluvium / granite	26.82	16.8	18.9	5093
53569	388082	5786441	Colluvium / granite	27.50	15.0	27.5	8682
53570	389790	5786764	Alluvium / granite	35.66	29.6	32.0	723
53571	389877	5786660	Alluvium / granite	28.65	26.8	28.6	884
53582	381773	5785744	Granite	36.00	31.0	36.0	1385
53583	381753	5785724	Granite	23.00	19.0	23.0	410
GBH 1A	385707	5788630	Granite	12.00		12.0	94
GBH 1	385707	5788630	Granite	41.50	26.0	32.0	53
GBH 2	386848	5788553	Granite	59.70	53.7	59.7	169
GBH 3A	386848	5788553	Granite	6.00		6.0	80
GBH 3	386469	5787861	Granite	35.50	29.5	35.5	260
GBH 4	385724	5787334	Granite	64.00	58.0	64.0	168

Note: "5000" numbered bores from GMS; "GBH" series bores from ATC Williams, 2009.

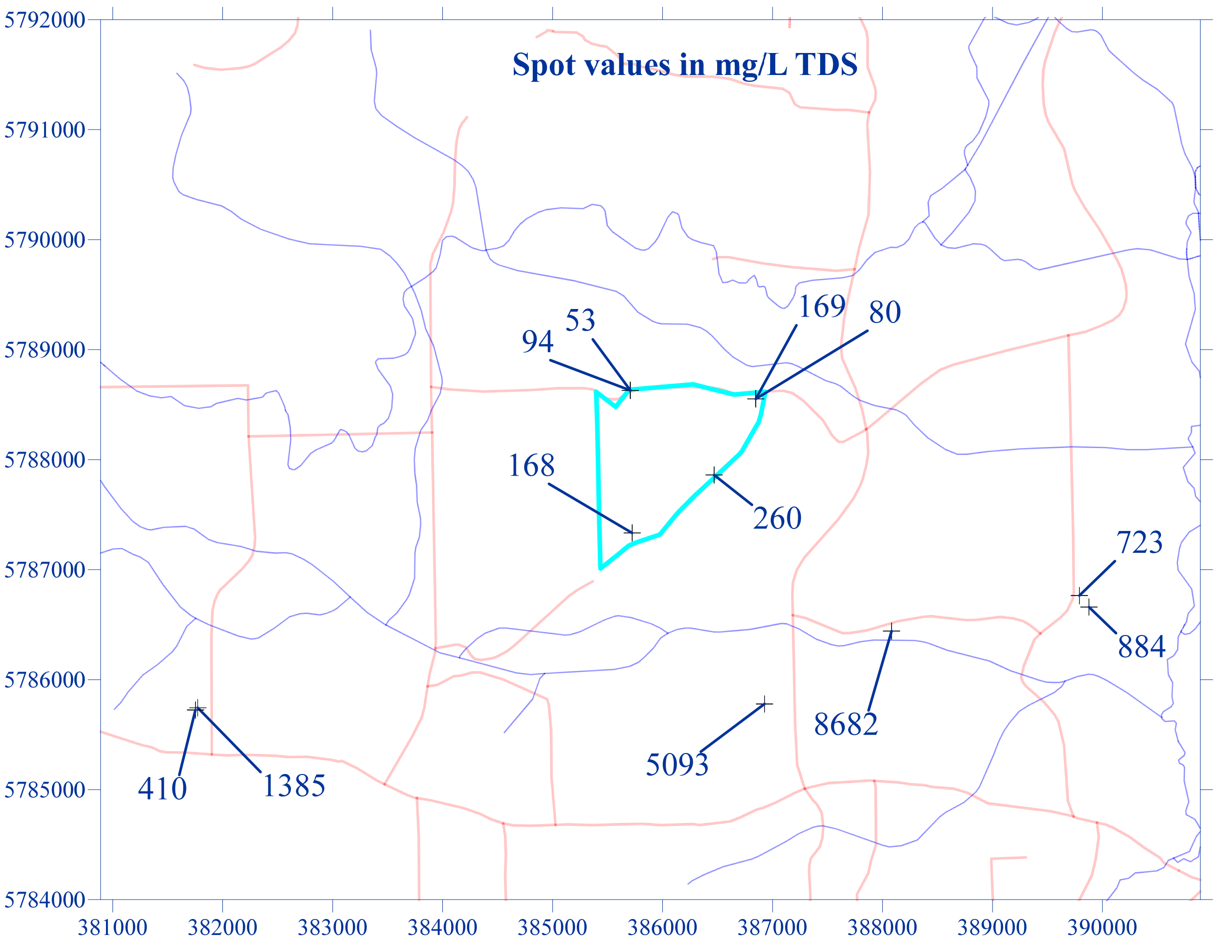


FIGURE 6.6 Reported Groundwater Salinities, Garfield North Area

6.3 WESTERN PORT BASIN TERTIARY AQUIFER SYSTEM

The Western Port Basin is a small (900 km^2), relatively shallow geological basin which has been infilled by Cainozoic sedimentary and volcanic rocks. The Tertiary sequence is up to 300 m thick in the southeastern part of the basin around Western Port Bay but thins landward wedging out landward along the basin margins. The approximate area of Tertiary rocks is indicated in Figure 6.7.

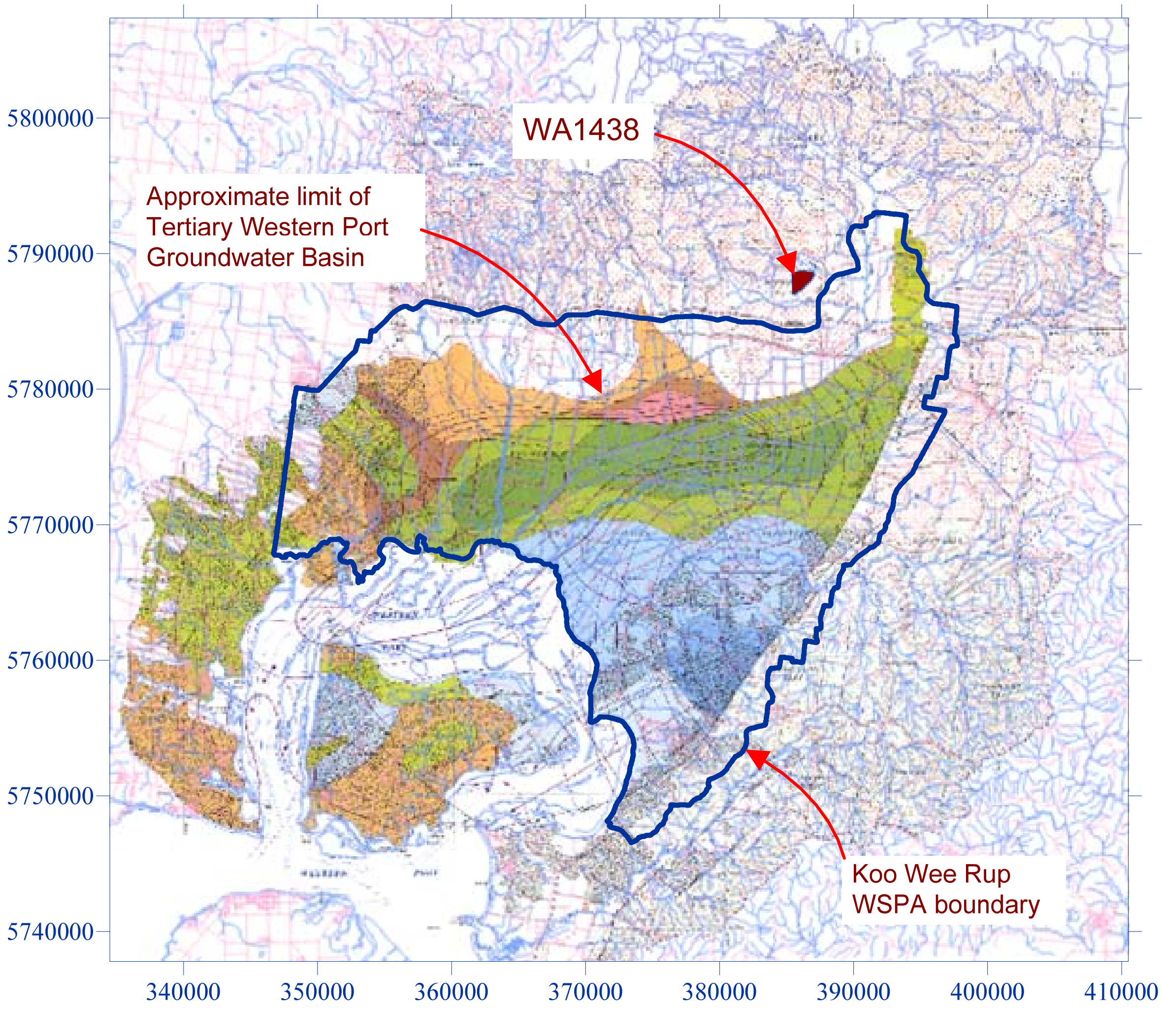


FIGURE 6.7 Western Port Hydrogeological Map (After Tickell and Lakey, 1982)

The main stratigraphic units in the basin are from oldest to youngest; 1) Childers Formation (sand, clay, gravel, conglomerate, thin brown coal seams); 2) Neerim Group Volcanics (Older Volcanics; basalt, basaltic clay), 3) Yallock Formation (sand, gravel), 4) Sherwood Formation and 5) Brighton Group formerly referred to as "Baxter Formation" (silt, sand, clay). The Yallock Formation, Sherwood Formation and Brighton Group were collectively referred to as the Western Port Group by Lakey and Tickell (1982). The Tertiary rock are covered by up to 70 m of unnamed Quaternary deposits (clay, peat, silt, sand minor gravel) over most of the Western Port Basin.

Lakey and Tickell (mapped) the Western Port Basin aquifer system extending along the Bunyip River in the Longwarry North-Labertouche-Tonimbuk area. The geological out crop pattern and limited lithologic logs in this area indicate the geology stratigraphic sequence in this area most likely consists of alluvium overlying Neerim Group Volcanics that rest directly on bedrock (Tynong Granite or Whitelaw Siltstone and that the Tertiary sedimentary units are not present.

The basal Tertiary unit in the Western Port Basin is the Childers Formation. The occurrence of this unit which is composed of sand and gravel with interspersed lignite and clay beds is restricted to the deeper parts of the basin towards Western Port Bay. Groundwater in the Childers Formation is confined to leaky confined. The Neerim Group Volcanic have widespread subsurface occurrence across the Western Port geological basin and is contiguous with outcrops in the Drouin-Warragul area. In the central and eastern part of the basin the basalt is relatively thick (up to 100 m) and is of sheet-like form. In these areas the basalt is overlain by a much thicker sequence (up to 200 m) of younger sediments. Pumping tests indicate complex boundary conditions. The basalt in the Nar-Nar-Goon area and the northeastern part of the Western Port Basin are relatively dense, have not developed high secondary porosity and generally have poor yield characteristics. In contrast, several test bores in the central part of the Basin have produced relatively high yields of 25 L/sec or more for small drawdown of the order of two metres. The Western Port Group includes the Brighton Group (formerly referred to as the Baxter Formation), and the Sherwood and Yallock formations. These sediments provide more than 80 per cent of the total extraction from the Basin. The Brighton Group has been extensively utilised and is particularly important throughout the major irrigation areas in the Dalmore–Cora Lynn area. Clay lenses interdigitate with coarse sand and gravel, and yields in excess of 25 L/sec have been obtained. The coarse sand and gravel of the Yallock Formation form the major aquifer throughout the western part of the basin where the unit is covered by up to 75 m of Quaternary clay. The Sherwood Formation is of considerable importance in the area to the east of Koo Wee Rup. Much of the formation consists of fine calcareous sand, but irrigation supplies of 10 to 15 L/sec are obtained from coarse shelly beds and occasional lenses of fractured limestone.

Aquifer parameters reported by Lakey (1980) are summarised in Table 6.2. The average, median and standard deviate for all the tests were 3.8, 2.9 and 2.8 m/day, respectively. GHD (2010) assigned lumped hydraulic conductivity value of 5 m/day to each of the Tertiary aquifers in the Western Port Basin for use in regional groundwater model developed as part of the DSE Ecomarkets project (Figure 6.8).

6.4 QUATERNARY DEPOSITS

The water table in the lower elevated areas surrounding the Tynong Granite occurs in the Quaternary alluvium which is locally relatively thin (10-20 m thick) and consists predominantly of fine grained material (clay, silt, sandy clay) with lesser sandy silty or sandy clay. Drilling along the highland front margins of the Western Port Basin indicate the alluvium rest directly on "bedrock". The finer facies of the alluvial deposits have high porosity but low specific yield and permeability.

TABLE 6.2 Interpreted Hydraulic Parameters, Western Port Aquifer System

Aquifer	Thickness (m)	Transmissivity (m2/day)	Storativity (dimensionless	Hydraulic conductivity (m/day)			
				Value	Average	Median	Stand Dev
Yallock Formation	50	100	0.0002	2.0			
	58	134		2.3			
	24	84	0	3.5			
	26	150	0.0027	5.7			
	21	100		4.8			
	42	191	0.35	4.6	3.8	4.1	1.5
Sherwood Formation	53	44	0.00021	0.8			
	20	27	0.00019	1.3			
	90	90	0.00028	1.0			
	7	18	0.00024	2.6			
	10	85	0.00011	8.5	2.8	1.1	3.2
Neerim Volcanic Group	23	64		2.8			
	14	41		2.9			
	40	13					
	39	141		3.6			
	26	34		1.3			
	33	2.9		0.1			
	72	640		8.9			
	17	130		7.6			
	53	496		9.4	4.6	3.3	3.6
Childers Formation	39	149		3.8			
Multiple	84	175	0.00113	2.1			

Note: Data from Lakey, 1980.

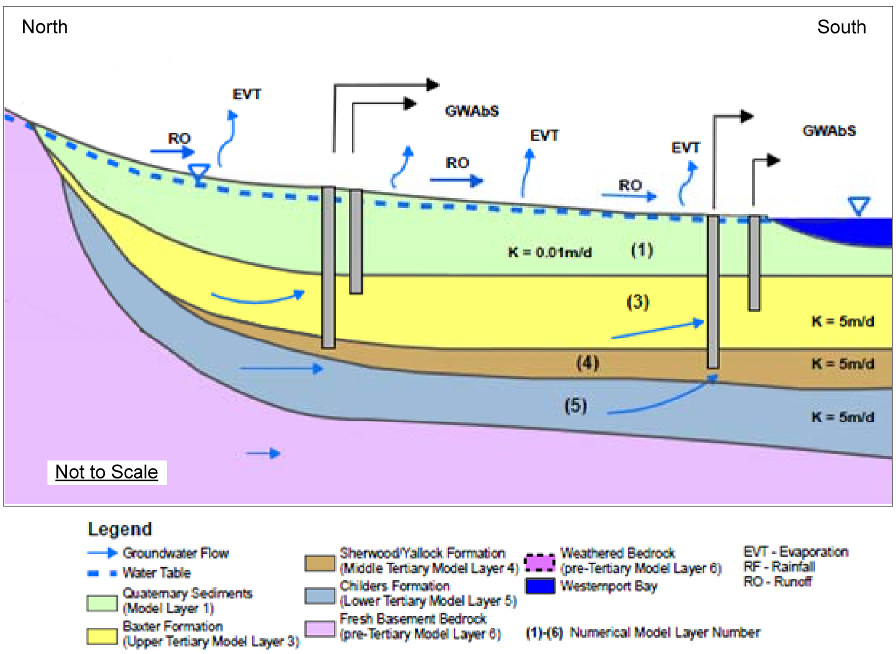


FIGURE 6.8 Generalised North-South Westernport Basin Hydrostratigraphic Cross-Section (modified after GHD, 2010)

The salinity of groundwater in the Quaternary deposits varies widely from less than 1,000 mg/L TDS to more than 4,000 mg/L TDS but is mostly greater than 1,500 mg/L TDS. The mapped salinity in the Officer-Pakenham-Pakenham South area varies between 2,200 and 6,000 mg/L but is mostly greater than 3,500 mg/L TDS (JLCS, 2010). The groundwater in Quaternary sediments at a site in Bunyip varied between 2,900 and 8,600 mg/L TDS, with average and median salinities of 6,820 and 8,600 mg/L TDS, respectively.

The salinity of groundwater from the Quaternary sediments in the Western Port Basin is mostly in the range from 1,500 to more than 12,000 mg/L TDS with the highest salinities general nearer to Western Port Bay. The mapped salinity in the Officer-Pakenham-Pakenham South area varies between 2,200 and 6,000 mg/L TDS but was mostly greater than 3,500 mg/L TDS. The groundwater in Quaternary sediments at a site in Bunyip varied between 2,900 and 8,600 mg/L TDS, with average and median salinities of 6,820 and 8,600 mg/L TDS, respectively (JLCS, 2010).

The permeability of the local alluvium has not been tested. However, the results of permeability tests (slug tests) on similar sediments in the Pakenham-Officer area (URS, 2003; Leonard, 2005; PB, 2011 area; summarised in Table 6.3) indicate that the predominantly clayey Quaternary deposits clays would be of low permeability and would function hydraulically as an aquitard (rather than as an aquifer).

TABLE 6.3. Western Port Basin Quaternary Deposits Hydraulic Conductivity

Bore	Location Project	URS (2003)	JLCS (2005)		PB (2011)
		Method not stated	Bouwer & Rice (1978)	Black (1976)	Bouwer & Rice (1978)
BH5	Pakenham		0.0096	0.0093	
BH6	Golf Course		0.0095	0.0081	
BH8			0.1	0.0000012	
MB01	Pakenham	0.3	0.102	0.136	
MB02	By-Pass	0.6	0.0115	NA	
MB03		0.007	0.006	NA	
MB04		0.009	0.0049	0.0043	
MB06		0.8	0.250	0.109	
MB07		0.003			
MW7	Officer				0.0128
MW8	Activity				0.0035
MW19	Centre				0.0027

Notes: 1) Units are m/day, 2) NA; Data not amendable to specified analysis method.

7.0 LOCAL GROUNDWATER USE AND BENEFICIAL USES

7.1 GROUNDWATER USE

Records of bores within a five kilometre radius of the approximate centre (centre of Stage 4 pit) of the proposed WA1438 Granite quarry extracted from state government Groundwater Management System (GMS; September 2012 update are provided by DSE). The data subset was further culled to only include supply bores by removing bores classified as observation, non-groundwater (NG) or investigation bores.

Thirty three registered "supply" bores are located within the stipulated search radius. Bore locations and recorded uses of all supply bores within the search area are posted on a (lightened) geological base map in Figure 7.1. [The location of bore S9034515/1 which plots on the WA1438 site should be verified in the field.]

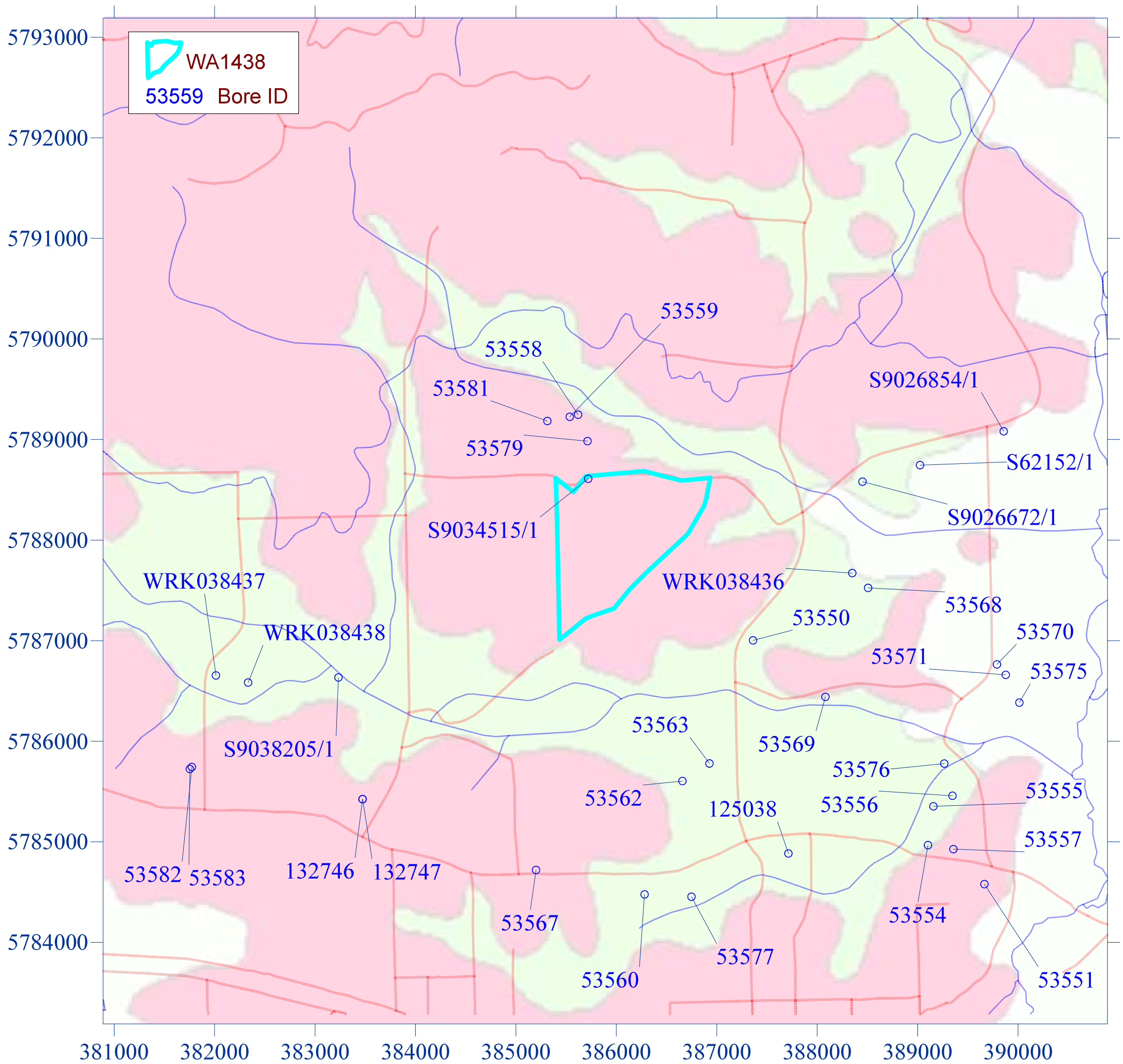


FIGURE 7.1 GMS Registered Supply Bores Within Five km Search Radius Centred on WA1438 Granite Quarry Pit Floor

The primary uses of 27 of the supply bores is recorded as Domestic and/or Stock bores, one as an irrigation bore (unlikely to be realised because of low bore yield), and five as unknown or not recorded (Figure 7.2; Table 7.1). The recorded depths of the bores range from about 1.8 to 123 m with a median depth of about 23 m with 85 per cent of the bores less than 40 m deep (Figure 7.3).

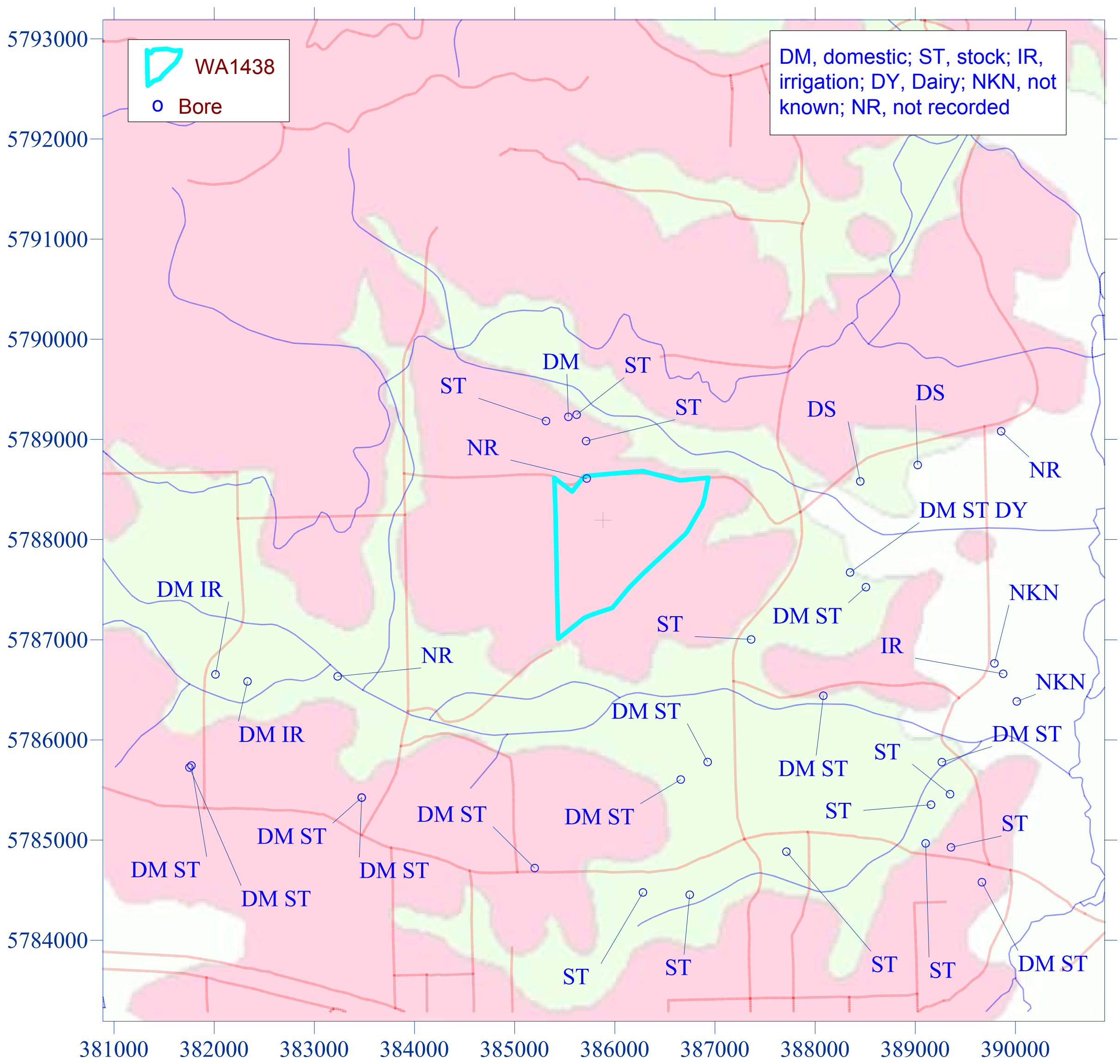


FIGURE 7.2 GMS Registered Uses of Supply Bores within Five km Search Radius Centred on WA1438 Granite Quarry Pit Floor

7.2 BENEFICIAL USES

The tested salinity of groundwater in the Tynong Granite at WA1438 is within groundwater beneficial use Segment A (refer Table 2.4). The beneficial uses for groundwater segment A to be protected under the SEPP *Groundwaters of Victoria (1997)* are:

- maintenance of ecosystems
- potable water supply
- potable mineral water supply
- agriculture, parks and gardens
- stock watering
- industry
- primary contact
- buildings and structures

TABLE 7.1 Bore Records Summary

Bore	MGA coordinates		Date	Elevation m AHD	Depth m bgl	Screens (mbgl)		TDS mg/L	Recorded Uses	Dist.* km
	Easting	Northing				From	to			
53550	387361.3	5787003.1	1/01/1970	65.5	9.70				ST	1.889
53554	389103.3	5784967.1	1/01/1970	59.4	4.57				ST	4.551
53555	389157.3	5785353.1	1/01/1970	55.8	20.40				ST	4.326
53556	389347.3	5785458.1	1/01/1970	57.4	9.10				ST	4.404
53557	389356.3	5784927.1	1/01/1970	76.9	8.80				ST	4.760
53558	385619.3	5789247.1	1/01/1970	93.8	1.80				ST	1.093
53559	385536.3	5789226.1	1/01/1970	101.0					DM	1.097
53560	386281.3	5784477.1	1/01/1970	53.1	5.50				ST	3.741
53562	386658.3	5785604.1	15/08/1972	69.0	22.86	16.76	18.89		DM ST	2.702
53563	386927.3	5785779.1	17/08/1972	70.0	26.82			5093	DM ST	2.628
53567	385200.2	5784720.1	1/03/1976	75.3	32.00				DM ST	3.544
53568	388507.3	5787525.1	1/02/1978	60.6	8.83	6.61	8.83		DM ST	2.695
53569	388082.3	5786441.1	4/03/1980	61.0	27.50	16.50	27.50	8682	DM ST	2.803
53570	389790.3	5786764.1	2/07/1980	55.8	35.66	29.57	32.00	723	NKN	4.146
53571	389877.3	5786660.1	11/07/1980	55.0	28.65	25.90	25.90	884	IR	4.264
53575	390013.3	5786384.1	19/04/1982	53.8	26.50				NKN	4.495
53576	389265.3	5785778.1	22/11/1982	58.6	8.25	6.00	8.25		DM ST	4.146
53577	386748.3	5784454.1	17/02/1984	53.2	19.35	16.35	19.35		ST	3.840
53579	385713.3	5788984.1	15/03/1983	100.4	30.50	28.00	30.50		ST	0.815
53581	385313.3	5789184.1	10/03/1983	122.2	14.00	5.50	14.00		ST	1.150
53582	381773.2	5785744.1	8/02/1990	94.4	36.00	31.00	36.00	1385	DM ST	4.783
53583	381753.2	5785724.1	26/02/1990	95.1	23.00	19.00	23.00	410	DM ST	4.811
125038	387713.3	5784884.1	16/09/1994	56.5	55.00	6.00	50.00		ST	3.780
132746	383473.2	5785424.1	4/10/1997	82.4	123.00				DM ST	3.674
132747	383473.2	5785424.1	24/04/1997	82.4	19.00				DM ST	3.674
S62152/1	389024.3	5788745.1	10/12/2003	57.4	12.00				DM ST	3.177
S9026672/1	388451.0	5788581.0	20/12/2006	62.9	20.00				DM ST	2.585
S9026854/1	389857.0	5789082.0		59.0	75.00				NR	4.058
S9034515/1	385720.0	5788610.0		95.2	70.00				NR	0.454
S9038205/1	383233.0	5786634.0		78.8	75.00				NR	3.076
WRK038436	388349.3	5787672.1	4/03/1973	61.8	16.15				DM ST DY	2.508
WRK038437	382013.2	5786654.1	8/08/1990	86.7	31.00	26.00	31.00		DM IR	4.163
WRK038438	382333.2	5786584.1	10/08/1990	82.5	33.00	28.00	33.00		DM IR	3.897

Notes: 1) GMS Registered bores within five km search radius of WA1438 Granite Extraction Pit. 2) Dist*, distance from approximate centre of Stage 4 Pit determined by JLCS using GIS software.

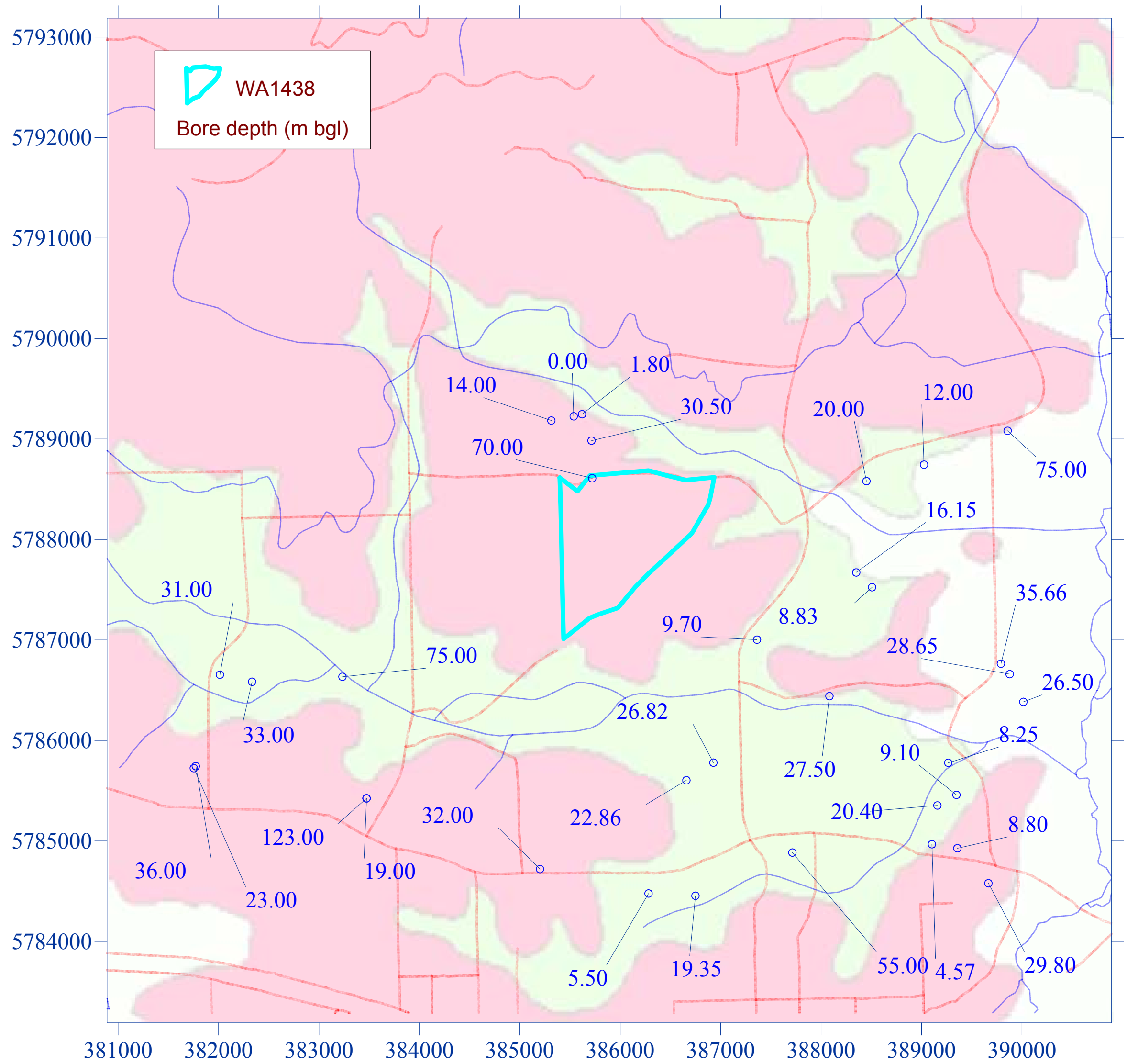


FIGURE 7.3 Recorded Depths of GMS Registered Supply Bores

The "Maintenance of Ecosystems" beneficial use is protected for all segments of groundwater in Victoria, and is one of the most sensitive beneficial uses to be protected. Groundwater discharge zone have not been identified but water table mapping indicates that groundwater that flows beneath WA1438 would discharge into the Bunyip River system.

Use of Segment A groundwater as a source of potable water is a protected beneficial use under the SEPP Groundwaters of Victoria. Potable water supply is a realistic groundwater beneficial use in area down-hydraulic gradient from WA1438.

Potable Mineral Water Supply is not a protected beneficial use in the Koo Wee Rup area as the groundwater is not classified as a mineral water in accordance with the definition in SEPP Groundwater of Victoria, is not effervescent (with respect to CO_2) and the area is not a proclaimed Mineral Water Reserve under the Water Act 1989 or is in a recognised mineral water province.

Use of Segment A groundwater for agriculture irrigation and watering parks and gardens is a protected beneficial use under the SEPP Groundwaters of Victoria. Groundwater from the Tynong Granite will not be required for agriculture irrigation at WA1438 and is unlikely to be required down hydraulic gradient from the site because of low bore yield potential.

Stock Watering is a protected beneficial use for Segment A groundwater. The area surrounding WA1438 is used for stock grazing. Consequently, stock water is a realistic beneficial use.

Industrial water uses defined in the ANZECC 1992 (Chapter 6 Industrial Water Quality) are generic processes (heating and cooling), hydroelectric power generation, textile industry, chemical and allied industry, food and beverage industry, iron and steel industry, tanning and leather industry, pulp and paper industry and the petroleum industry. Although the groundwater is suitable for a wide range of industrial uses, it is considered unlikely that there will be any demand for industrial water in the future except for processing and dust suppression at the proposed quarry.

The “Primary Contact Recreation” beneficial use category relates to the use of groundwater to fill swimming pools or where groundwater discharges into a water body that could be used for swimming. Although it is unlikely that swimming pools would be constructed down hydraulic gradient from WA1438 given the low bore yield potential, high bore installation, and running and maintenance costs, it is possible that receiving surface waters could be used for swimming and other recreational activities.

The “Building and Structures” beneficial use is protected for all segments of groundwater in Victoria. Groundwater should therefore not be made corrosive to buildings and structures due to onsite activities.

Any potential contamination activities at the site such as storage and use of diesel fuel should be in accordance with best practice to ensure that local groundwater and receiving surface waters are not contaminated.

8.0 CONCEPTUAL HYDROGEOLOGICAL MODEL

8.1 GROUNDWATER FLOW IN HILLY TERRAINS

WA1438 is situated in hilly terrain (but not mountainous). A brief description of the theory of groundwater flow in hilly terrains is presented here as background to developing a regional conceptual groundwater flow model for the Garfield North area.

Depending on the drainage basin topography and the basin-shape geometry, flow systems may have regional; local; local and intermediate; or local, intermediate, and regional components. Generally only regional systems develop where local relief is negligible but if the surface topography has well-defined local relief, a series of *local groundwater flow systems* form because the topographic relief causes undulations in the water table. The more pronounced the relief of the undulating water table, the deeper the local flow systems extend (Toth, 1963).

Local flow systems are recharged in "local" topographic highs with discharge into adjacent topographic lows (Figure 8.1). They are shallower, with short flow paths and the size of the recharge area is much greater with respect to the volume of water in the aquifer. Local flow systems are areas of rapid circulation of groundwater; groundwater in these systems is therefore much more active in the hydrologic cycle than groundwater in regional flow systems (Toth 1963). Spring discharge of local flow systems is closely related to recharge of precipitation and shows wide fluctuations as well as great disparity in water quality.

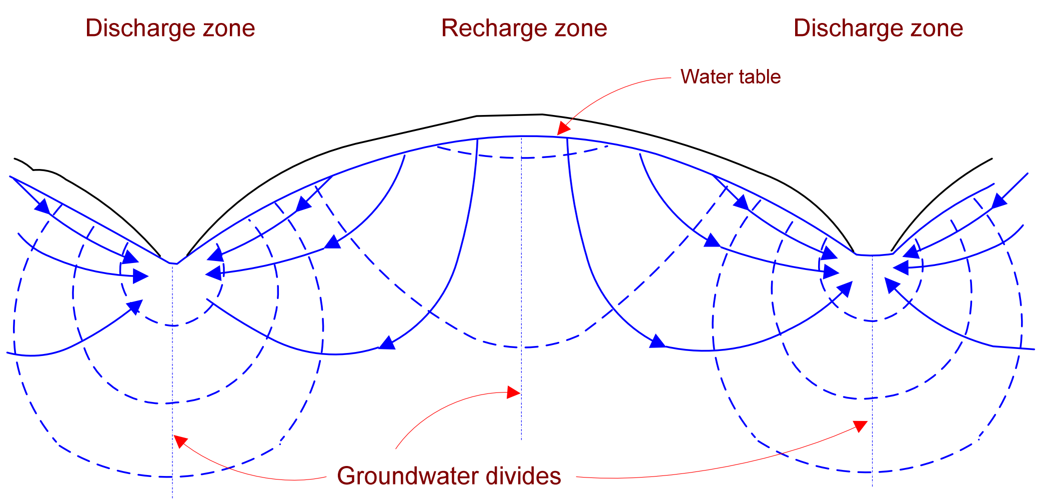


FIGURE 8.1 Local Groundwater Flow System Model

Groundwater flow beneath the hilltops/ridges is downward into the granite with groundwater flow beneath the deeper valleys upward with groundwater discharging in the valley floors and into the streams. The crest of the water table is a groundwater divide with flow on either side going in opposite directions. Similarly, permanent streams are also groundwater divides.

8.2 GROUNDWATER FLOW SYSTEMS BENEATH WA1438

An approximate northeast-southwest conceptual groundwater flow cross-section through WA1438 extending to bore 106099 near Bayles is presented Figure 8.2. The flow system is considered to consist of shallow circulating local flow cells beneath hills developed on a more deeply circulating regional flow system [The mapped water table beneath WA1438 (see Figure 3.4) is consistent with the model presented in Figure 8.2.]

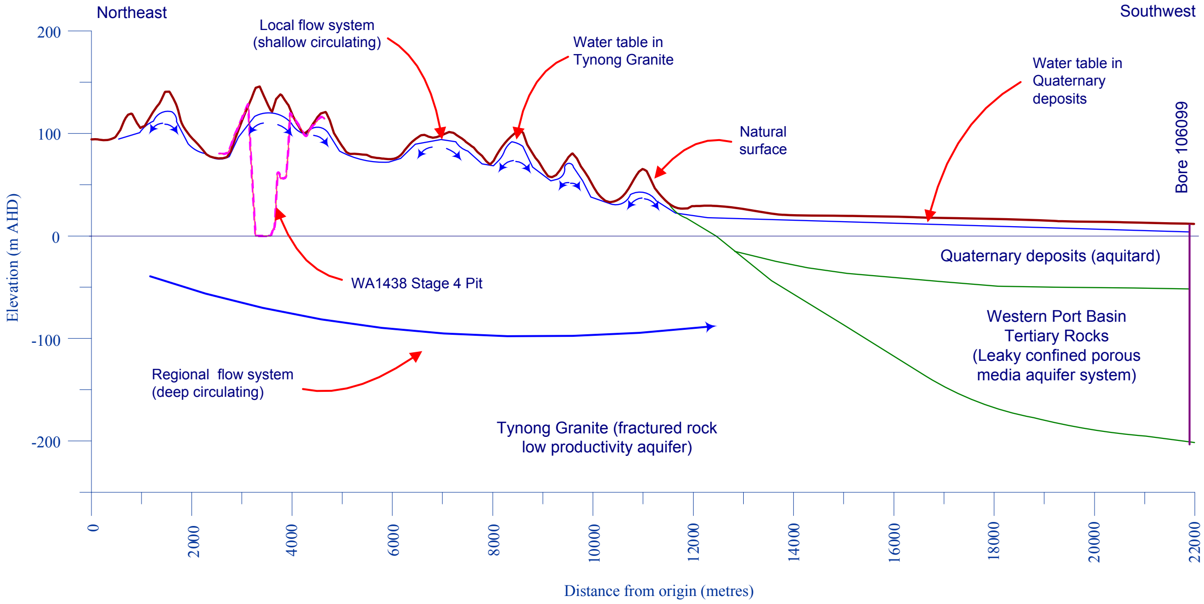


FIGURE 8.2 Northeast-Southwest Conceptual Groundwater Flow Model Through WA1438 and Portion of Western Port BasinD

Water table contours and groundwater flow direction vectors beneath WA1438 and the immediate surrounding area are presented in Figure 8.3. The position of the water table beyond the WA1438 site was inferred from the mapped local topography; the contours were topographically enforced" so that the water table was below ground level. Although the contours are not based on actual water level data beyond WA1438 they are indicative of the general water table configuration in the local hilly terrain. The water table position indicated in Figure 8.2 shows that the water table configuration in the hilly terrain in the Garfield North area would be complex and would require numerous bores to produce a regional water table map.

8.3 GROUNDWATER RECHARGE/DISCHARGE

The near-surface geologic materials and the structure and permeability of the underlying bedrock and local topography control the quantity of direct infiltration and the generation of runoff, and whether basins are likely to be dominated by runoff or by infiltration and groundwater direct groundwater recharge: WA1438 is situated in hilly terrain where groundwater flow is generated only by the infiltration of surface water. The quantity of recharge that reaches the water table in hilly terrain is governed by surficial and near-surface processes of rainfall, evapotranspiration, infiltration, and runoff. The physical properties of the soil, such as soil water storage and infiltration capacity, along with evapotranspiration, dictate whether percolating water will reach the soil-bedrock interface. Infiltrating water will either percolate into fractures rock, pond where it can be removed by evapotranspiration, move down dip and then percolate into the rock mass, or remerge at downslope seeps or springs to become runoff to nearby stream channels.

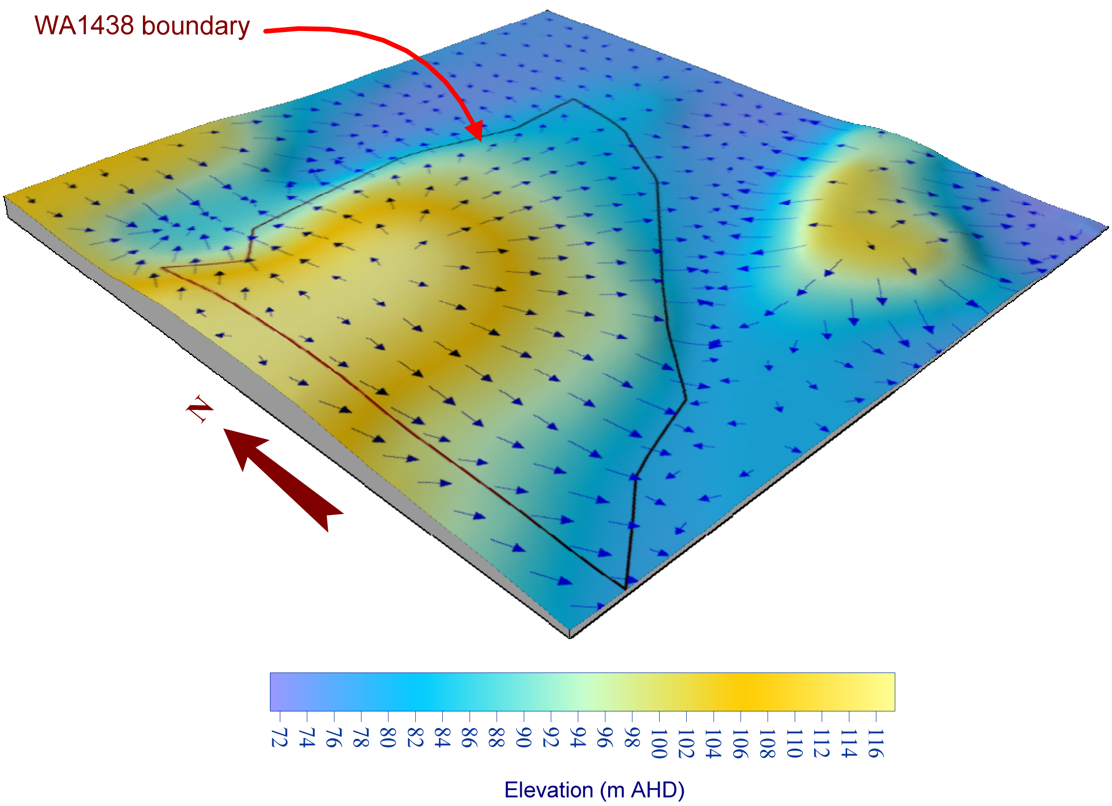


FIGURE 8.3 Water Table Elevation and Groundwater Flow Directions

Recharge areas cover much of the area (usually in topographical high areas). A characteristic of hilly terrain is the occurrence of upward vertical hydraulic gradients in valley floors. Consequently, groundwater discharge occurs via baseflow contributions into creeks and upward leakage into overlying soils on valley floors. Flow lines diverge from recharge areas and converge toward discharge areas. Minor discharge zones can develop at higher elevations on valley sides where the water table intersects the ground surface.

9.0 GROUNDWATER FLOW INTO QUARRY PITS

9.1 THEORETICAL CONSIDERATIONS

The proposed granite quarry will extend up to 100 metres below the water table. Groundwater will drain into the pit by gravity drainage as the local discontinuities in the granite are dewatered. [The drawdown vortex created around the pit is referred to as a “cone of depression” and the area affected by the gravity drainage is referred to as the “area of influence”.] Drawdown at any point within the area of influence is directly proportional to the discharge rate and inversely proportional to aquifer transmissivity and aquifer storativity with transmissivity exerting a greater influence than storativity. The Tynong Granite has exceedingly low transmissivity and low storativity, consequentially the cone of depression around the proposed pit would be very steep and relatively localised (i.e., of high vertical magnitude and of narrow horizontal extent).

Cones of depression have circular cone-like form in isotropic aquifer where the water table is flat-lying (Figure 9.1) but if the water is sloping the cone will be asymmetrical and elongated in the hydraulic gradient direction (Figure 9.2). Elliptical cones of depression can develop in anisotropic rocks such as fractured granite (Figure 9.3). In all water-table situations, however, a “cone of depression” of whatever form defines a region of the aquifer that has been drained of water.

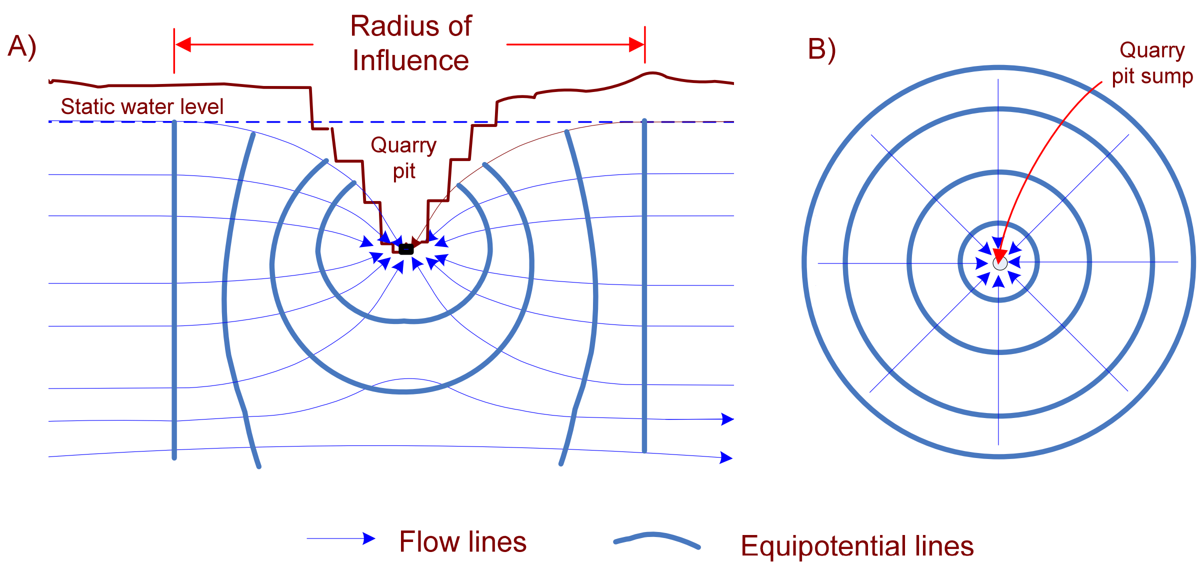


FIGURE 9.1 Drawdown Cone Around Quarry Pit in an Ideal Aquifer in Flat-Lying Water Table in Isotropic Aquifer, A) Sectional View and B) Plan View

The water table in the hilly terrain in the Garfield North area has the form of a series of local mounds formed on a sloping regional water table (see Figure 8.1) with groundwater flowing towards WA1438 from the more elevated terrain to the west and northwest. Although the shape of the cone of depression around the proposed WA1438 quarry cannot be predicted with certainty, it is likely that the initial cone would be relatively regular but would become elongated (long axis in the hydraulic gradient direction) as the local groundwater mound at is drained with the cone of depression expanding on a sloping water table. The form of the drawdown cone could be distorted by any as of yet undetermined directional variations in the hydraulic conductivity of the fractured granite mass.

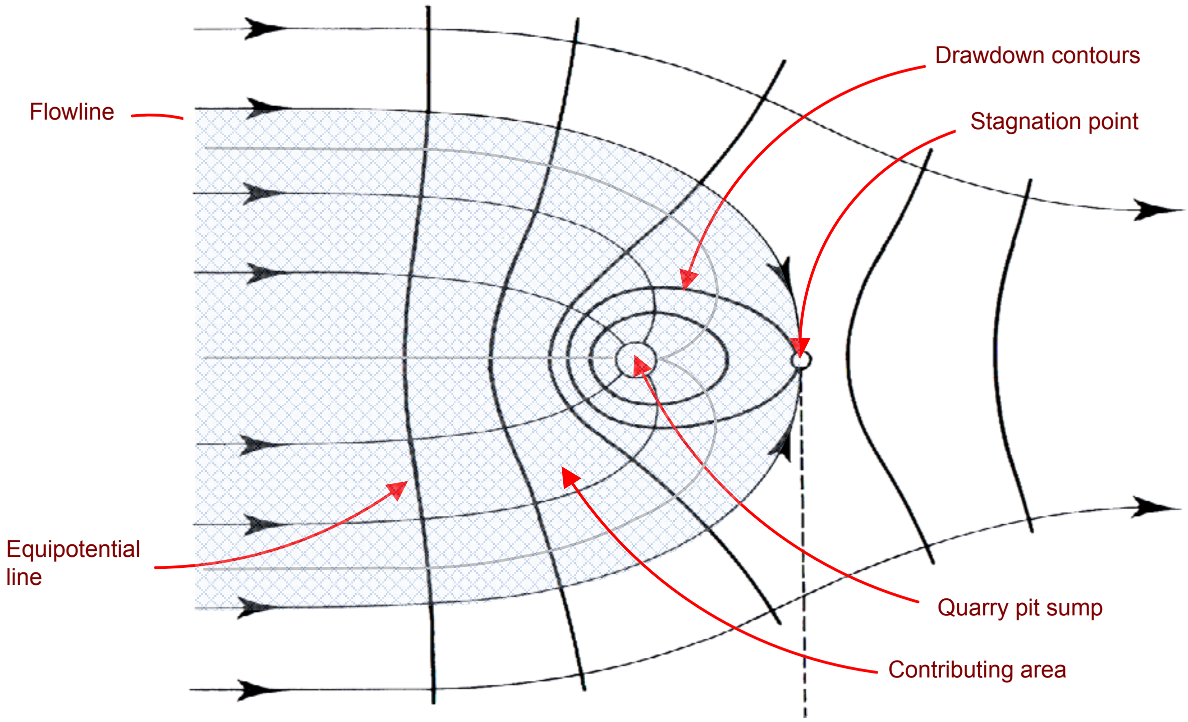


FIGURE 9.2 Flowlines, Equipotential Lines and Contributing Area on Sloping Water Table Schematic

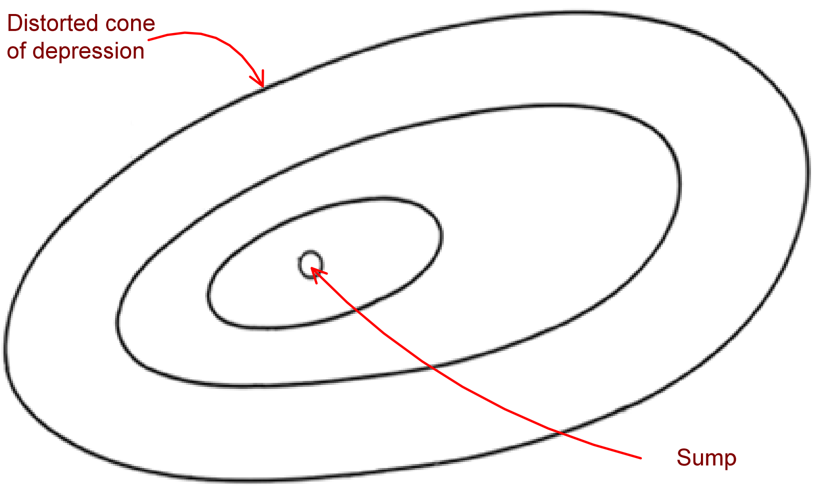


FIGURE 9.3 Elongated Cone of Depression in Anisotropic Fractured Rock Aquifer

9.2 RADIUS OF INFLUENCE

The radius of influence is the lateral extent of the cone of depression under a given set of conditions (time, recharge, discharge). Since radius of influence depends on the balance between aquifer recharge and discharge, the radius can vary depending on climatic conditions because the hydraulic conductivity of the granite is very low the dewatering cone of depression will be very steep and relatively localised.

The radii of influence around the proposed WA1438 quarry pit was computed using two different empirical equations namely, 1)Sichardt's equation for unconfined aquifers (Eq 9.1), and 2) Bear's 1979 equation for confined aquifers (Eq 9.2). Both equations are estimates only and were used here to provide an indication of the likely radius of influence. Neither equation includes a recharge term and therefore would over-estimate drawdown (all other factors being equal).

$$Ro = 3000\,(H - h)\,\sqrt{K} \qquad \text{Eq 9.1}$$

$$R(t) = 1.5\,(Tt/S)^{1/2} \qquad \text{Eq 9.2}$$

where

R = radius of influence (m)
t = time (days)
T = Transmissivity (m^2/day)
S = Storativity (dimensionless)
H = initial head in aquifer (m)
h = head in dewatered aquifer (m)
K = hydraulic conductivity (m/sec)

The radii of influence were estimated based on aquifer permeability coefficients (transmissivity or hydraulic conductivity) determined from analysis of the permeability test and pumping test data. The storativity was assumed to be 0.1 (specific yield of 10%): Sichardt's equation does not include "time" and estimates the steady-state radius of influence whereas Bear's equation includes time as a variable.

The steady state radii of influences based on hydraulic conductivities of 1.06 x 10-7 and 3.0 x 10-7 m/sec calculated using Equation 9.1 were about 390 and 657 m, respectively.

The radii of influence for time periods up to 50 years calculated using Bear's equation are for transmissivities determined from aquifer tests in site bores, 1.1 and 3.12 m^2/day, and conservative value of 10 m^2/day are presented in Table 9.1. The radii calculated using Bear's equation were greater than those using Sichardt's equation. Consequently, JLCS used the Bear radii of influence in identifying the area likely to experience drawdown interference assuming a quarry operating life of 50 years, as shown in Figures 9.4, 9.5 and 9.6.

TABLE 9.1 Radii of Influence (m) from Bear's Equation

Time (years)	Transmissivity (m^2/day)			Time (years)	Transmissivity (m^2/day)		
	1.1	3.12	10		1.1	3.12	10
0.003	5	8	15	10	301	506	906
0.08	27	46	82	15	368	620	1,110
0.2	43	73	130	20	425	716	1,282
0.4	61	103	184	25	475	800	1,433
0.6	74	124	222	30	521	877	1,570
0.8	85	143	255	35	562	947	1,695
1	95	160	287	40	601	1,012	1,812
2	134	226	405	45	638	1,074	2,026
5	213	358	641	50	672	1,132	2,026

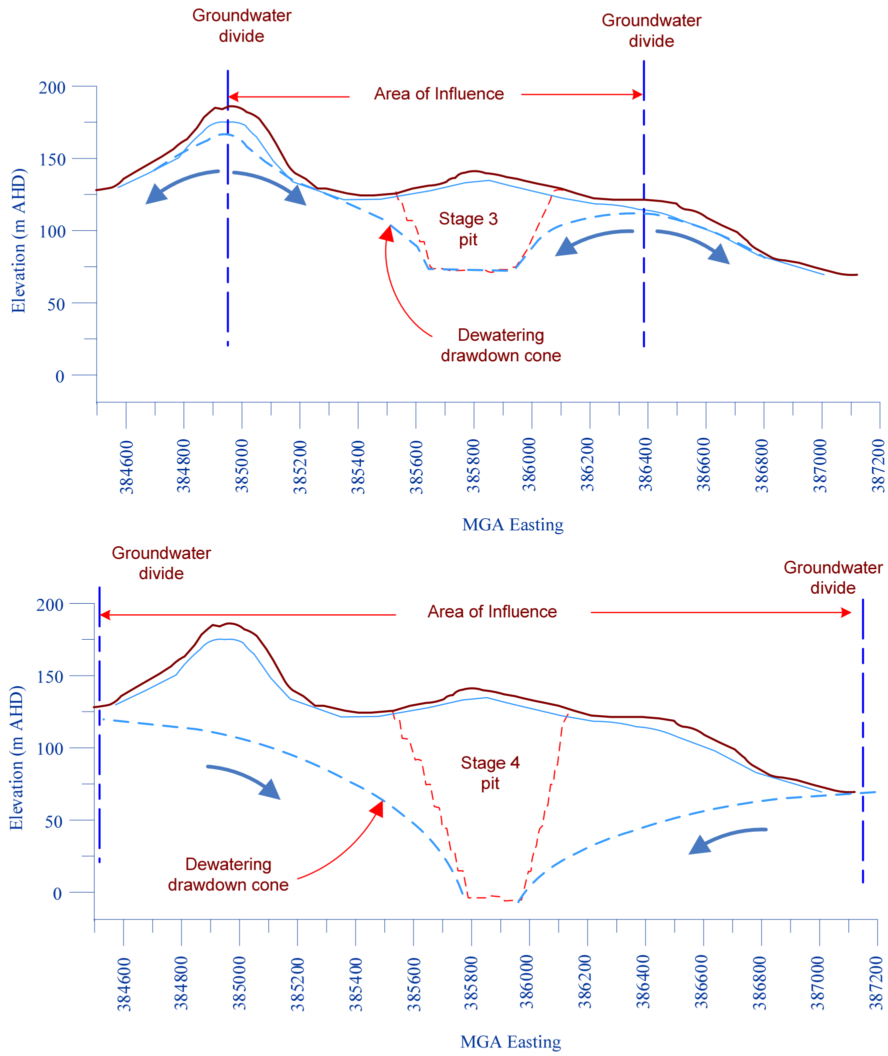


FIGURE 9.4 Schematic of Area of Influence of WA1438 Stage 3 and Stage 4 Pits

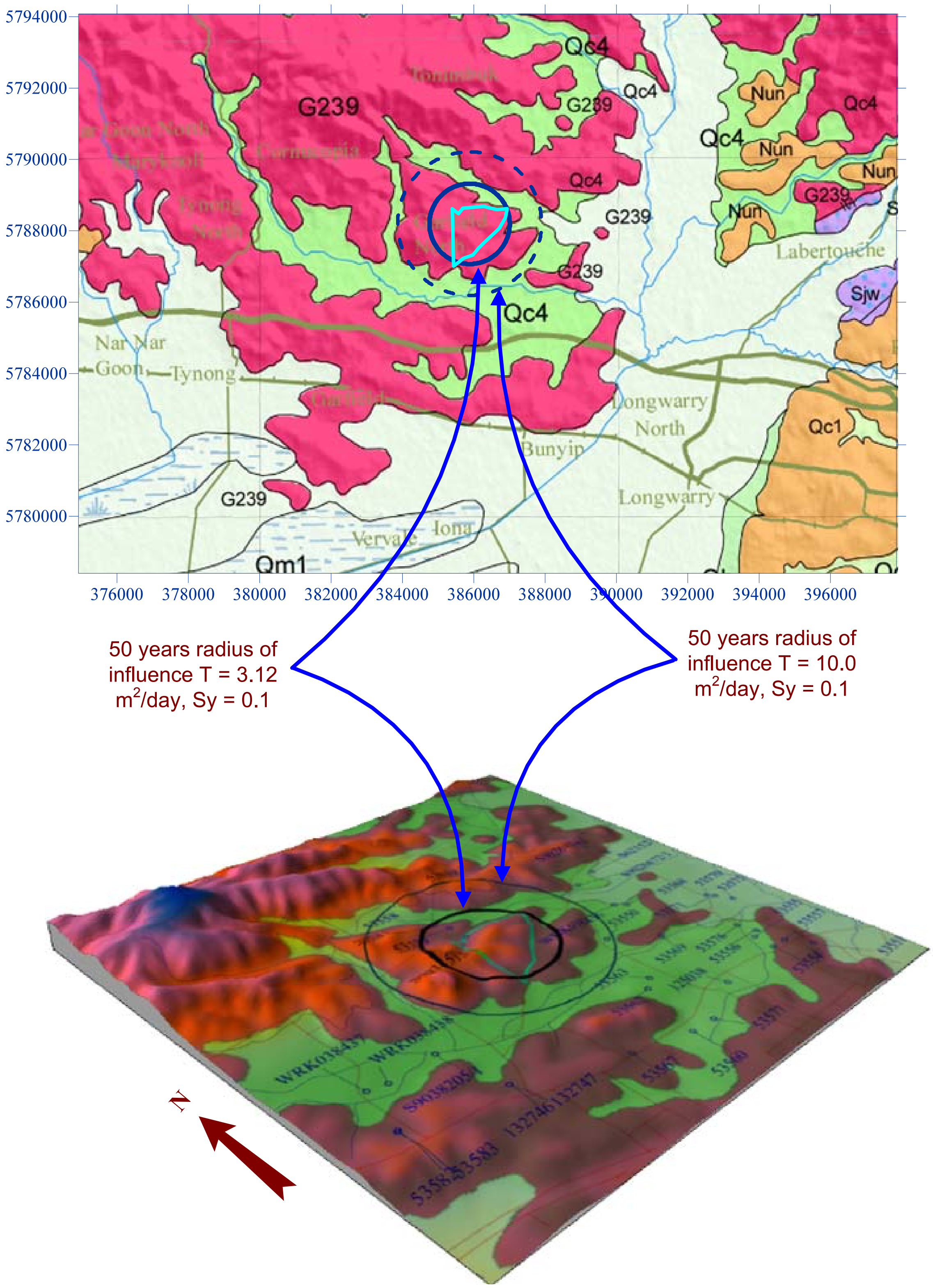


FIGURE 9.5 Radii of Influence from Bear's Equation Superimposed on Local 2D- and 3D Geological Maps

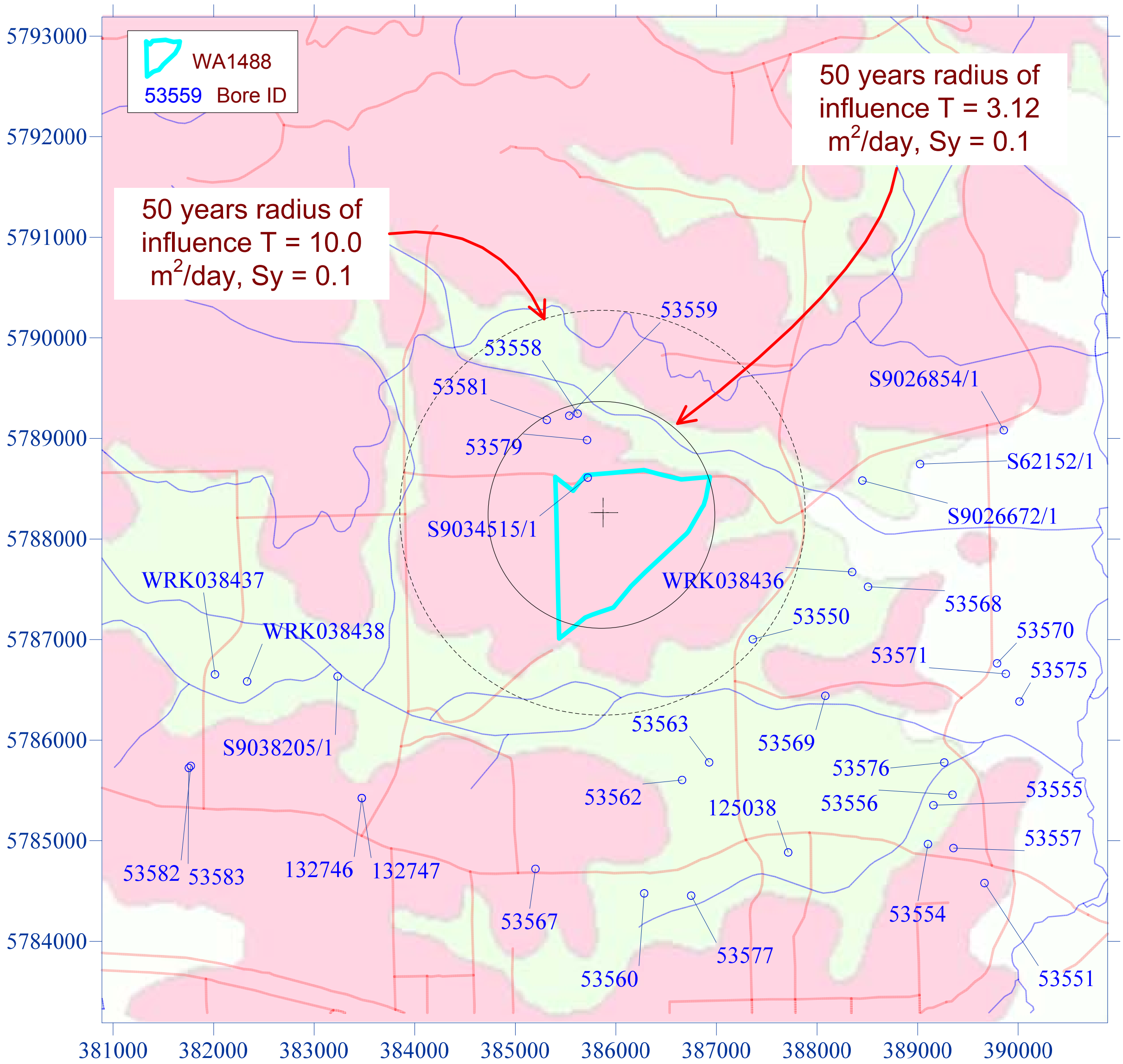


FIGURE 9.6 Radii of Influence from Bear's Equation Superimposed on Local Geological Map with Plotted Bore Locations

9.3 TOPOGRAPHIC CONTROL OF DRAWDOWN CONE

Although the extent of the drawdown cone cannot accurately be predicted because of the anisotropic nature of the fractured granite and the hilly terrain, it can be stated with a high degree of confidence that the drawdown cone would not affect groundwater in the aquifers to the northeast, east and south of WA1438 until the water table is lowered to about 74 m AHD (the level of the proposed Stage 3 pit floor) based on the local topography, as illustrated in Figures 9.7 and 9.8. It should be noted that the 74 m AHD contour is beyond the 50 year radius of influence estimated using Bear's equation.

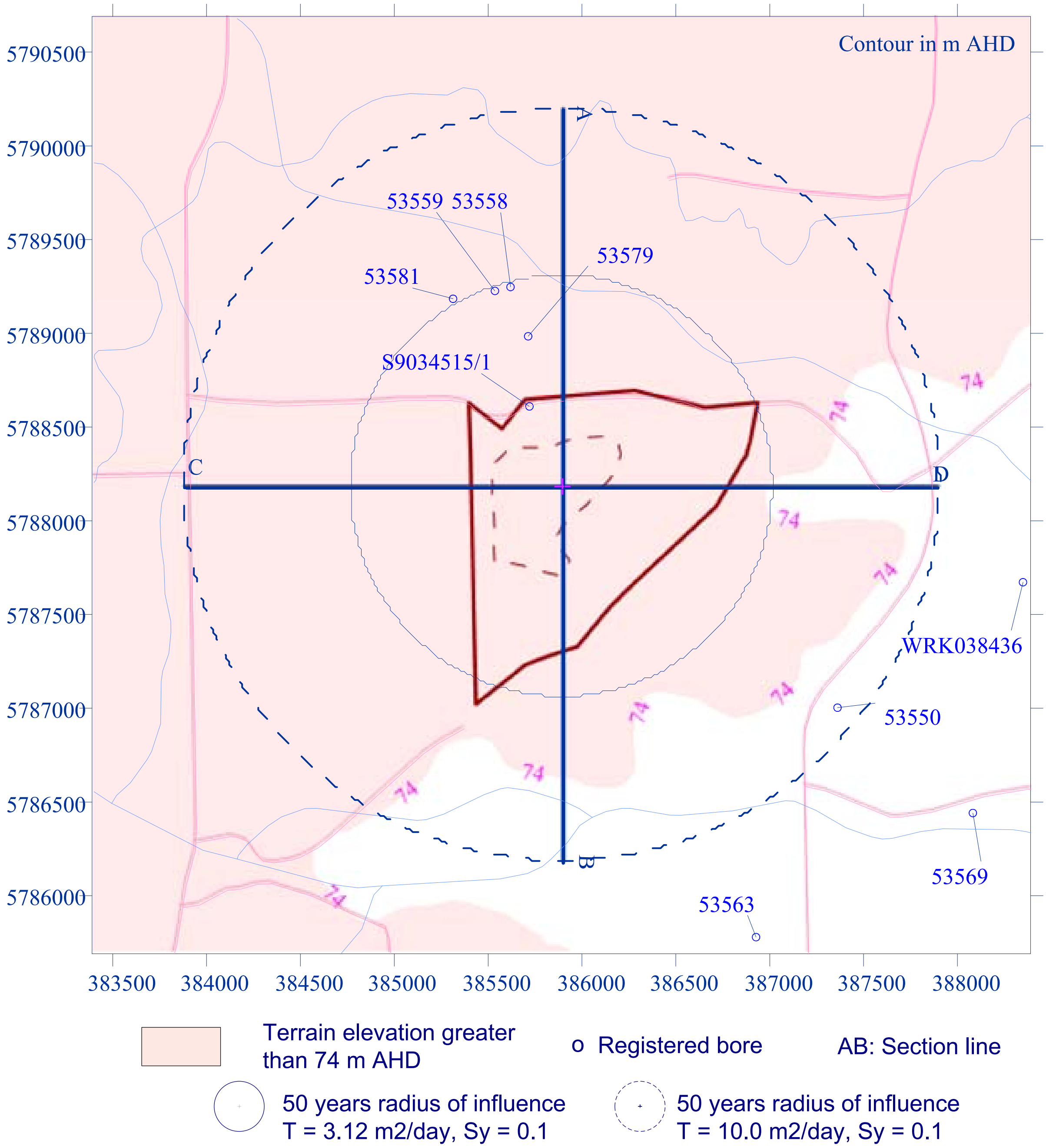


FIGURE 9.7 Elevation Greater Than 74 m AHD Area

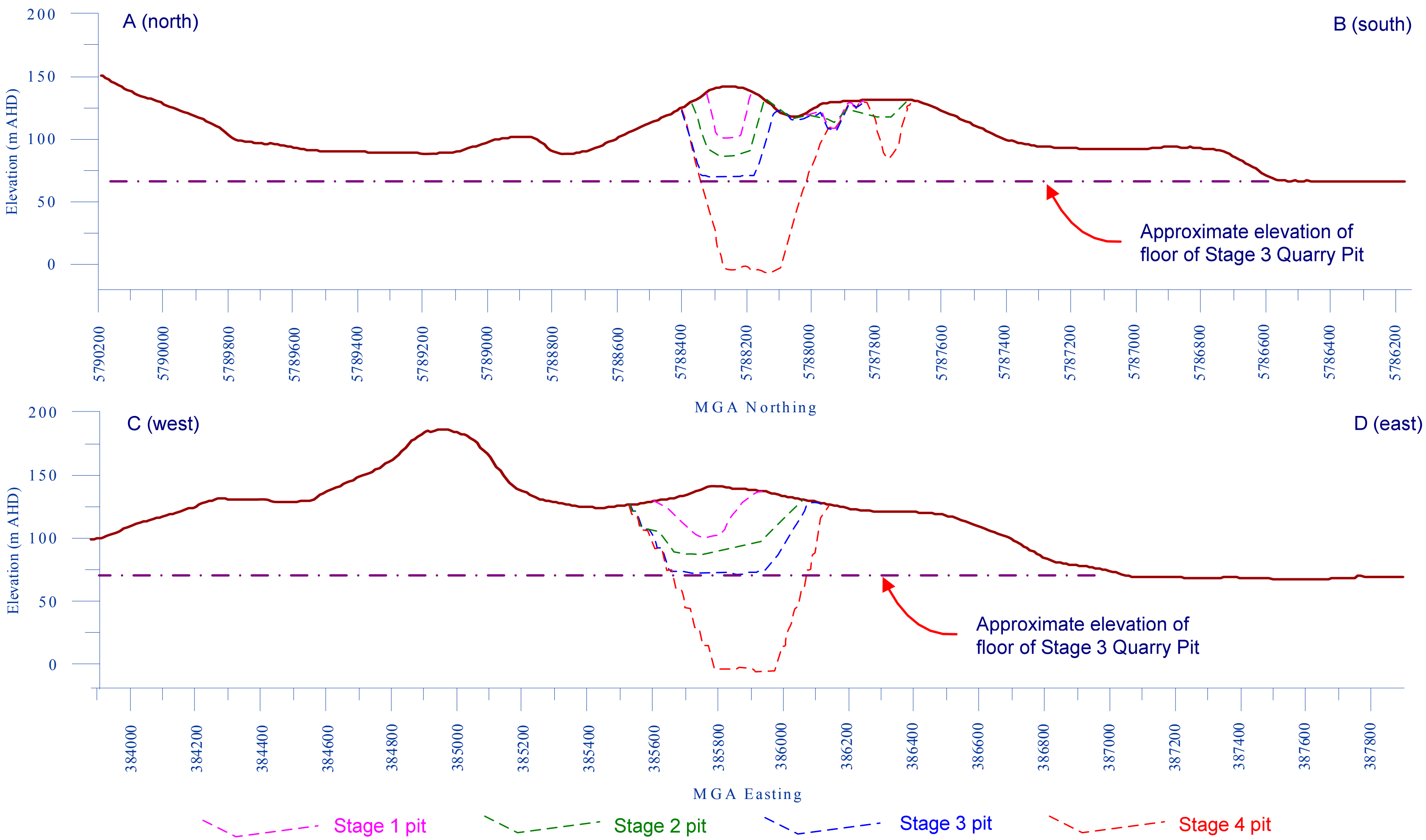


FIGURE 9.8 North-South and West-East Topographic Profiles Through WA1438 Showing Quarry Pit Stages

10.0 DEWATERING IMPACTS, MONITORING AND MITIGATION

10.1 POTENTIAL IMPACT

10.1.1 Local Groundwater Users

Water bores within the zone of influence resulting from the dewatering of the WA1438 Quarry Pit could potentially to be affected by the lowering of the water table in the quarry sump. Records in the GMS database indicate that there are 33 supply bores with a five km search radius of the approximate centre of the WA1438 quarry pit but only five are within a one km radius the WA1438 quarry pit as plotted from bore coordinates reported in the GMS database. The registered numbers of the five bores within close proximity to WA1438 which are most likely to experience (dewatering) drawdown interference are S9034515/1, 53579, 53581, 53558 and 53559. These bores are located northwest of WA1438..

10.1.2 Water Resource in Other Aquifers

Other aquifers in the Garfield North area that could be affected by the proposed quarry are the alluvium aquifer mainly to the east of the site and underlying Tertiary rocks (most likely Neerim Volcanic Group), if present. However, it is considered that any impact due to the proposed quarry would only be minor. Although dewatering could (slightly) lower the water table beyond the granite outcrop areas it is not expected to significantly lower the water table in the surrounding alluvial deposits. Lowering the water could increase the effectiveness of the man-made drains in the area which would be beneficial in controlling water logging and problems associated with shallow water tables.

The main aquifers within the Tertiary Western Port Groundwater Basin are seven km southwest from the WA1438 quarry pit. The hydrogeological analysis undertaken for this report (based on distribution of the outcropping Tynong Granite, granite hydraulic parameters, local topography and groundwater flow system analysis) indicate that the drawdown cone associated with quarrying at WA1438 will not impact on the Tertiary aquifers in the Western Port Groundwater Basin.

10.1.3 Potential Impact on Local Streamflow

Dewatering at the proposed WA1438 quarry could potentially affect stream flow by 1) intercepting groundwater flow that would have otherwise discharged in streams as baseflow, 2) by lowering the water table beneath streams causing induced streambed infiltration, or 3) indirectly by reducing vertical (upward) discharge from the Tynong Granite into the alluvium where it overlies the granite. The baseflow in the streams surrounding WA1438 is considered to be mostly derived from shallow groundwater within the alluvium with a relatively small contribution via (vertically) upward groundwater discharge from the underlying aquifers including the Tynong Granite.

10.2 MONITORING

10.2.1 Rainfall

Measuring local rainfall is required to establish the relationship between groundwater levels and stream flows to climate so as to separate any effects of the pit dewatering from the natural climatic variations.

Consideration should also be given to establishing an evaporation pan on site and measuring evaporation losses for use in water balance modelling.

10.2.2 Pit Inflow

Measuring the surface area of pit sump(s) and recording the volume of water pumped from the sump(s) pit is required for water balance modeling. The data would also enable groundwater inflow to be separated from surface water inflow which could be back substituted in analytical equations.

10.2.3 Groundwater Monitoring

A network of monitoring bores should be established prior to the commencement of quarrying operations at WA1438. The network should include off-site bores as well as on-site bores. The expanded monitoring bore network would enable more accurate water table mapping and assessment of dewatering impacts on local groundwater users and any interconnected waterways. Regular groundwater level monitoring would enable groundwater level drawdown to be identified prior to any impacts being experienced in surrounding landholder bores and enable assessment of the impacts of local streams. [The JLCS recommended monitoring bore network is detailed in Section 11.2.] Consideration should also be given to monitoring private bores to provide data on actual drawdown interference (rather than predicted or hearsay).

10.2.4 Stream Monitoring

Consideration should be given to establishing a stream monitoring program in addition to the recommended groundwater and pit inflow monitoring. The monitoring should concentrate on summer months to determine whether the local streams are intermittent (only flow in response to surface runoff) or permanent with flow during dry period maintained by groundwater discharge (baseflow).

11.0 CONCLUSIONS AND RECOMMENDATIONS

11.1 CONCLUSIONS

Hanson propose to develop a hard rock quarry in an area of outcropping granite at Garfield North in the foothill of the Eastern Highlands (Great Dividing Range). The proposed quarry site is located within the parish of Bunyip in the Cardinia Shire. WA1438 is in an unincorporated area (i.e., not within a Groundwater Water management area).

The DPI Works Authority number for the proposed quarry is WA1438. The WA1438 Work Plan seeks approval for a final Extraction Pit area of approximately 33 hectares. The granite Extraction Pit will be developed in four stages. The pit perimeter and pit floor area for each stage are indicated in Figure 1.5 and visualization of the four pits are presented in Figure 1.6. The approximate elevations of the base of the Stage 1, Stage 2, Stage 3 and Stage 4 quarry pit floor will be about 100, 85, 75 and 0 m AHD, respectively. The final Stage 4 pit depth will be about 140 metres below the present ground surface in the highest area of the proposed quarry.

WA1438 is not located within a groundwater management or groundwater water supply protection area. The closest declared groundwater management area is the Koo Wee Rup Water Supply Protection Area which is about 1,150 m from WA1438 at their closest points and about 1,750 m from the approximate centre of the proposed Stage 4 pit.

The topography in the Garfield North area is very hilly with WA1438 situated on a relatively small local hill that attains an elevation in excess of 140 m AHD. Runoff to the north of the main approximate west-east trending ridge at the site flows into a minor unnamed tributary of Two Mile Creek West. Runoff to the south of the main ridge and east of the secondary ridge flows either directly or via two gullies into a second unnamed tributary of Two Mile Creek West. Runoff from the southwestern corner of the sites flows into Cannibal Creek. Both Two Mile Creek West and Cannibal Creek flow in general easterly directions into the Bunyip River. The Bunyip River flows south to the confluence with the Tarago River. South of the Nar Nar Goon – Longwarry Road (east of the Bunyip township) the Bunyip River has been altered into a man-made channel as part of extensive Koo Wee Rup Swamp drainage works which were commenced in the late 1880s. Man-made realignment of creeks and constructed drain are evident to the north of the Princess Highway on the Bunyip River system alluvial flats. Part of the Two Mile Creek West system also appears to have been channelized as indicated by unnaturally straight stream segments.

The outcropping granite at WA1438 is referred to as Tynong Granite. Quaternary alluvium overlying at least in part Neerim Group (Older Volcanics) rocks is mapped to the east of WA1438 along the Bunyip River system. Western Port Basin Tertiary rocks are about seven km from the quarry pit at its closet margins.

The granite at WA1438 varies from highly weathered to fresh and is varyingly fractured with fracture density and openness likely to decrease with depth. Permeability testing at WA1438 indicates that the granite has very low hydraulic conductivity.

The shallow water table beneath WA1438 is characteristic of low permeability sediments in hilly areas. The flow system is consider to consist of shallow circulating local flow cells beneath hills developed on a more deeply circulating regional flow system

The proposed granite quarry will extend up to 100 metres below the water table. Groundwater will drain into the pit by gravity drainage as the local discontinuities in the granite are dewatered. The expansion of the cone of depression will be controlled by the permeability of the fractured granite. The Tynong Granite has exceedingly low transmissive and low storativity, consequentially the cone of depression around the proposed pit would be very steep and relatively localised (i.e., of high vertical magnitude and of narrow horizontal extent).

Predicting the extent of the drawdown cone in fractured rock aquifers is problematic. Although the extent of the drawdown cone cannot accurately be predicted because of the anisotropic nature of the fractured granite and the hilly terrain, it can be stated with a high degree of confidence that the drawdown cone would not affect groundwater in the aquifers to the northeast, east and south of WA1438 until the water table is lowered to about the 74 m AHD (the level of the proposed Stage 3 pit floor) Groundwater monitoring to obtain actual water level data is considered to be more important than undertaking numerical modelling to simulate the likely drawdown response to quarry dewatering as the simulated water levels in fractured rock aquifers in hilly terrains would have an associated high level of uncertainty and could well be misleading.

11.2 RECOMMENDATIONS

11.2.1 Monitoring Bore Network

- The monitoring bore network should be expanded to include offsite monitoring bores as well as additional onsite bores prior to commencing quarrying operations. The expanded monitoring bore network would enable more accurate water table mapping and assessment of dewatering impacts and local groundwater users and any interconnected waterways. Regular groundwater level monitoring would also enable groundwater level drawdown to be identified prior to any impacts being experienced in surrounding landholder bores and enable assessment of the impacts of local streams.

  - Four addition deep monitoring bore should be installed around the perimeter of WA1438 (Figure 11.1) and monitored together with the existing four deep, perimeter monitoring bores (GBH 1, GBH 2, GBH 3 and GBH 4) to enable the site water table to be more accurately mapped.

  - A network of monitoring bores should also be installed offsite to provide data on the water table level beyond the WA1438 site boundary. The off-site bores would most likely have to be installed on road reserves which is a constraint on locating bores and would require permission from the Cardinia Shire Council as well as bore construction licences from Southern Rural Water. Tentative locations for eight off-site bores are indicated in Figure 11.2. [Off-site bore locations would need to be selected during a local area reconnaissance survey.] The off-site bore would not have to be drilled as deep as the onsite bores because drawdown decrease with increasing distance from the quarry.

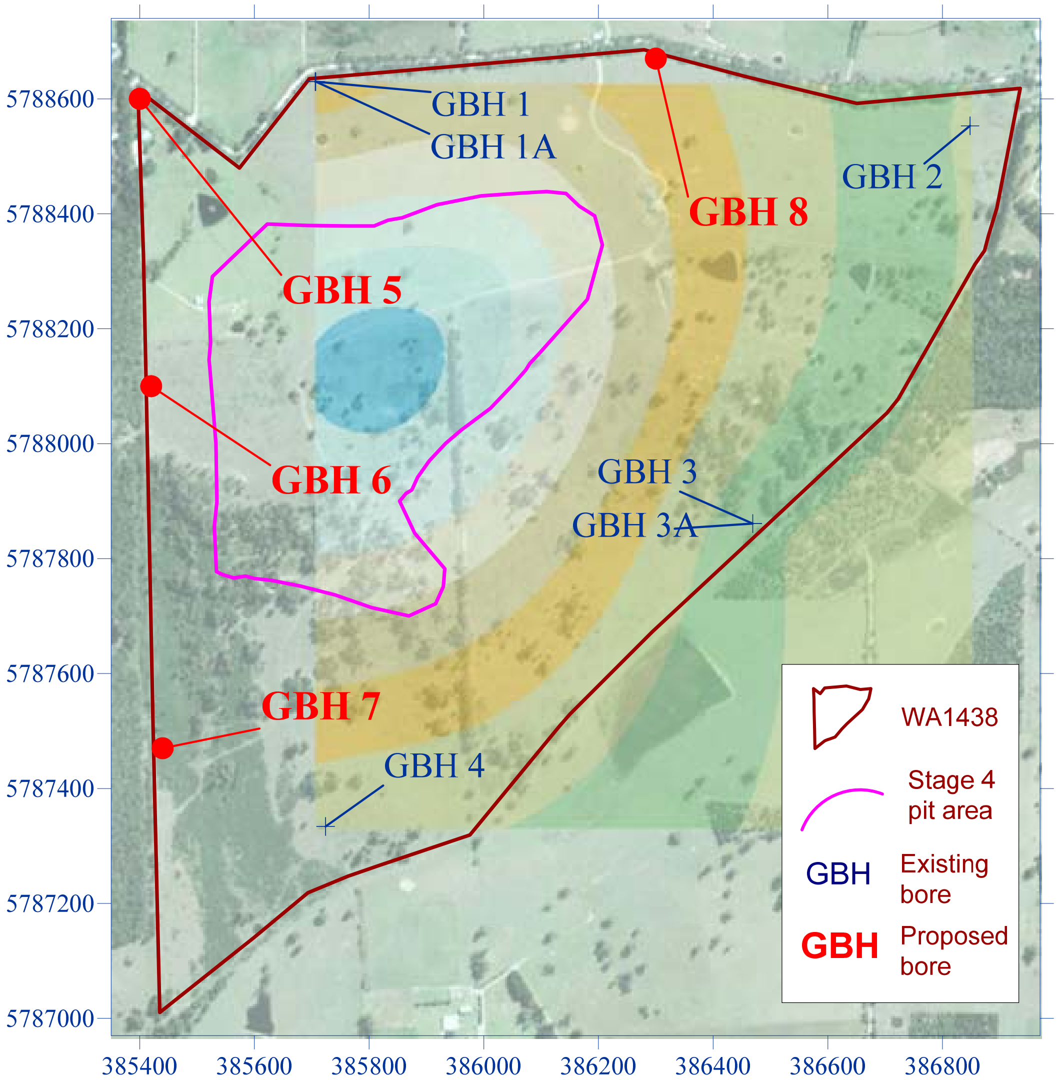


FIGURE 11.1 Proposed Locations of Additional On-Site Monitoring Bores

11.2.2 Monitoring Program

- Water levels in the purpose-installed monitoring bores should be measured at least every three months to enable the depth to groundwater to be mapped and to establish the relationship between rainfall and water table elevation.

- Local creeks should be inspected every three months and observation of flow conditions photographed and recorded (particularly import during summer) to enable assessment of the relationship between groundwater and stream flow.

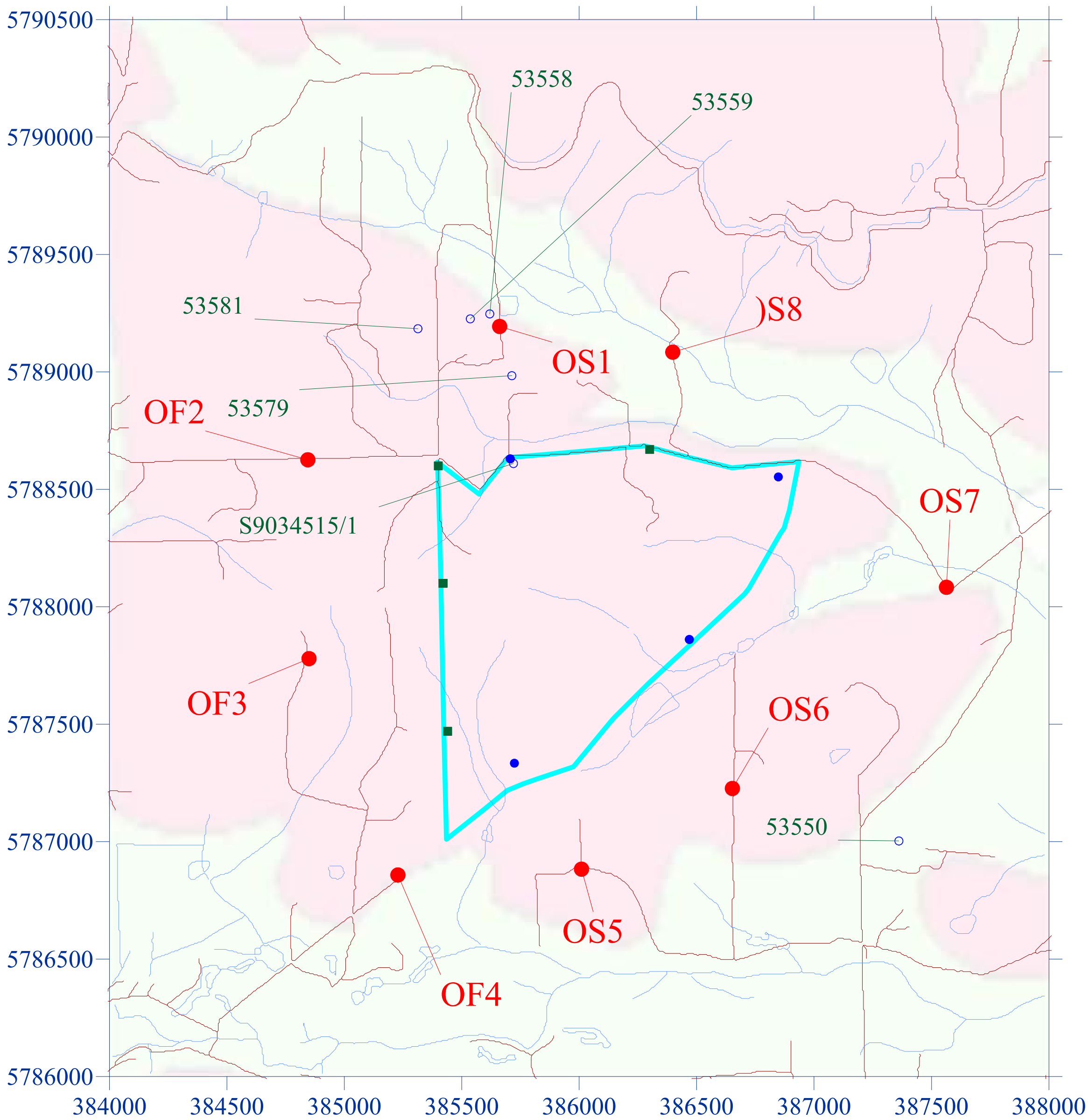


FIGURE 11.2 Tentative Locations of Proposed Off-Site Monitoring Bores

- Samples of groundwater from the on-site monitoring bores should be analysed for standard water quality parameters to verify the identified Groundwater Beneficial Uses and for use in determining option for use and/or disposal water from quarrying dewatering works.

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13.0 LIMITATIONS OF THIS REPORT

The advice provided in this report relates only to the project described herein and must be reviewed by a competent Engineer or Scientist before being used for any other purpose. JOHN LEONARD CONSULTING SERVICES Pty Ltd accepts no responsibility for other use of the data.

Drill hole and laboratory tests used in this report was performed and recorded by others. This data is included and used in the form provided by others. The responsibility for the accuracy of such data remains with the issuing authority, not with JOHN LEONARD CONSULTING SERVICES Pty Ltd.

The advice tendered in this report is based on information obtained from the investigation locations, test points and sample points and is not warranted in respect to the conditions that may be encountered across the site at other than these locations. It is emphasized that the actual characteristics of the subsurface and surface materials may vary significantly between adjacent test points and sample intervals and at locations other than where observations, explorations and investigations have been made. Sub-surface conditions, including groundwater levels and contaminant concentrations can change in a limited time. This should be borne in mind when assessing the data.

An understanding of the site conditions depends on the integration of many pieces of information, some regional, some site specific, some structure-specific and some experienced-based. This report should not be altered, amended or abbreviated, issued in part and issued incomplete in any way without prior checking and approval by JOHN LEONARD CONSULTING SERVICES Pty Ltd. JOHN LEONARD CONSULTING SERVICES Pty Ltd accepts no responsibility for any circumstances which arise from the issue of the report which has been modified in any way as outlined above.

John Leonard

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March 2013

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