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**OPEN FILE
REPORT
SERIES**

INVESTIGATION OF HYDROGEOCHEMICAL DISPERSION OF GOLD AND OTHER ELEMENTS IN THE WOLLUBAR PALAEODRAINAGE, WESTERN AUSTRALIA

Volume I

D.J. Gray

CRC LEME OPEN FILE REPORT 33

September 1998

(CSIRO Division of Exploration Geoscience Report 387R, 1993.
Second impression 1998)

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INVESTIGATION OF HYDROGEOCHEMICAL DISPERSION OF GOLD AND OTHER ELEMENTS IN THE WOLLUBAR PALAEODRAINAGE, WESTERN AUSTRALIA

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RESEARCH ARISING FROM CSIRO/AMIRA REGOLITH GEOCHEMISTRY PROJECTS 1987-1993

In 1987, CSIRO commenced a series of multi-client research projects in regolith geology and geochemistry which were sponsored by companies in the Australian mining industry, through the Australian Mineral Industries Research Association Limited (AMIRA). The initial research program, "Exploration for concealed gold deposits, Yilgarn Block, Western Australia" (1987-1993) had the aim of developing improved geological, geochemical and geophysical methods for mineral exploration that would facilitate the location of blind, buried or deeply weathered gold deposits. The program included the following projects:

P240: Laterite geochemistry for detecting concealed mineral deposits (1987-1991). Leader: Dr R.E. Smith.
Its scope was development of methods for sampling and interpretation of multi-element laterite geochemistry data and application of multi-element techniques to gold and polymetallic mineral exploration in weathered terrain. The project emphasised viewing laterite geochemical dispersion patterns in their regolith-landform context at local and district scales. It was supported by 30 companies.

P241: Gold and associated elements in the regolith - dispersion processes and implications for exploration (1987-1991). Leader: Dr C.R.M. Butt.
The project investigated the distribution of ore and indicator elements in the regolith. It included studies of the mineralogical and geochemical characteristics of weathered ore deposits and wall rocks, and the chemical controls on element dispersion and concentration during regolith evolution. This was to increase the effectiveness of geochemical exploration in weathered terrain through improved understanding of weathering processes. It was supported by 26 companies.

These projects represented "an opportunity for the mineral industry to participate in a multi-disciplinary program of geoscience research aimed at developing new geological, geochemical and geophysical methods for exploration in deeply weathered Archaean terrains". This initiative recognised the unique opportunities, created by exploration and open-cut mining, to conduct detailed studies of the weathered zone, with particular emphasis on the near-surface expression of gold mineralisation. The skills of existing and specially recruited research staff from the Floreat Park and North Ryde laboratories (of the then Divisions of Minerals and Geochemistry, and Mineral Physics and Mineralogy, subsequently Exploration Geoscience and later Exploration and Mining) were integrated to form a task force with expertise in geology, mineralogy, geochemistry and geophysics. Several staff participated in more than one project. Following completion of the original projects, two continuation projects were developed.

P240A: Geochemical exploration in complex lateritic environments of the Yilgarn Craton, Western Australia (1991-1993). Leaders: Drs R.E. Smith and R.R. Anand.

The approach of viewing geochemical dispersion within a well-controlled and well-understood regolith-landform and bedrock framework at detailed and district scales continued. In this extension, focus was particularly on areas of transported cover and on more complex lateritic environments typified by the Kalgoorlie regional study. This was supported by 17 companies.

P241A: Gold and associated elements in the regolith - dispersion processes and implications for exploration. Leader: Dr. C.R.M. Butt.

The significance of gold mobilisation under present-day conditions, particularly the important relationship with pedogenic carbonate, was investigated further. In addition, attention was focussed on the recognition of primary lithologies from their weathered equivalents. This project was supported by 14 companies.

Although the confidentiality periods of the research reports have expired, the last in December 1994, they have not been made public until now. Publishing the reports through the CRC LEME Report Series is seen as an appropriate means of doing this. By making available the results of the research and the authors' interpretations, it is hoped that the reports will provide source data for future research and be useful for teaching. CRC LEME acknowledges the Australian Mineral Industries Research Association and CSIRO Division of Exploration and Mining for authorisation to publish these reports. It is intended that publication of the reports will be a substantial additional factor in transferring technology to aid the Australian Mineral Industry.

This report (CRC LEME Open File Report 33) is a first revision of CSIRO, Division of Exploration Geoscience Restricted Report 387R, first issued in 1993, which formed part of the CSIRO/AMIRA Project P241A.

Copies of this publication can be obtained from:

The Publication Officer, CRC LEME, CSIRO Exploration and Mining, PMB, Wembley, WA 6014, Australia. Information on other publications in this series may be obtained from the above or from <http://leme.anu.edu.au/>

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Appendix 1 - Compiled Analytical Results

Appendix 1: Compiled Analytical results

| | Sample | pH | Eh | TDS | Na.i | Mg.i | Ca.i | K.i | Cl.ic | SO4.ic | HCO3. at | Br.ic | I.ic | F.ic | PO4. pm | Cat-An /Total | Sr.i | Cs.m | Ba.i |
|----|-----------------------------|------|-----|--------|-------|------|------|-----|-------|--------|-------------|-------|------|------|------------|------------------|------|-------|-------|
| 1 | Chlorite Schist-Golden Hope | 6.37 | 238 | 40515 | 10685 | 2460 | 858 | 142 | 21300 | 5070 | 572 | 77 | 1.50 | <0.5 | 0.02 | 0.00 | 6.3 | 0.002 | 0.006 |
| 2 | HW64 | 4.16 | 483 | 88327 | 27825 | 3606 | 508 | 258 | 49800 | 6330 | 0 | 102 | 0.23 | 3.3 | 0.02 | 0.00 | 4.7 | 0.006 | 0.035 |
| 3 | HW51 | 4.90 | 398 | 60305 | 18550 | 2629 | 337 | 310 | 32900 | 5580 | 11 | 110 | 0.39 | 4.8 | 0.02 | 0.00 | 3.6 | 0.009 | 0.025 |
| 4 | HW1 | 4.74 | 472 | 87756 | 28270 | 3419 | 572 | 95 | 50000 | 5400 | 18 | 54 | 0.19 | < 1 | 0.02 | 0.01 | 5.3 | 0.006 | 0.024 |
| 5 | HW4 | 4.56 | 450 | 89049 | 28493 | 3413 | 593 | 90 | 51100 | 5360 | 23 | 55 | 0.14 | 1.8 | 0.02 | 0.00 | 5.8 | 0.006 | 0.027 |
| 6 | HW7 | 4.51 | 468 | 92438 | 29457 | 3540 | 626 | 105 | 53100 | 5610 | 22 | 56 | 0.27 | 2.1 | 0.02 | 0.00 | 5.9 | 0.006 | 0.029 |
| 7 | HW6 | 4.59 | 458 | 93094 | 29606 | 3600 | 601 | 108 | 53500 | 5680 | 22 | 57 | 0.17 | 1.5 | 0.02 | 0.00 | 5.8 | 0.006 | 0.012 |
| 8 | Poly 1 | 3.24 | 509 | 45640 | 14172 | 1918 | 415 | 55 | 26400 | 2680 | 0 | 42 | 0.15 | 2.1 | 0.09 | 0.00 | 4.2 | 0.000 | 0.040 |
| 9 | Uncased 1 | 5.56 | 313 | 45398 | 13727 | 1966 | 618 | 67 | 25600 | 3420 | 152 | 43 | 0.27 | < 1 | 0.02 | 0.00 | 4.7 | 0.000 | 0.040 |
| 10 | JP1 | 3.17 | 523 | 50510 | 15582 | 2183 | 197 | 309 | 27800 | 4440 | 0 | 99 | 0.44 | 5.6 | 0.02 | 0.00 | 3.1 | 0.013 | 0.023 |
| 11 | Shear Zone - Golden Hope | 6.21 | 144 | 50498 | 13282 | 3383 | 729 | 284 | 27000 | 5820 | 548 | 90 | 2.57 | < 1 | 0.12 | 0.00 | 9.8 | 0.067 | 0.059 |
| 12 | Ultramafic - Golden Hope | 6.46 | 203 | 43430 | 12317 | 2466 | 84 | 353 | 22200 | 6010 | 956 | 91 | 4.18 | <0.5 | 0.34 | -0.01 | 4.1 | 0.075 | 0.044 |
| 13 | NB-1 | 5.52 | 254 | 105174 | 32425 | 3871 | 640 | 107 | 61400 | 6730 | 17 | 59 | 0.26 | < 1 | 0.02 | -0.03 | 10.6 | 0.008 | 0.037 |
| 14 | NB-2 | 5.53 | 233 | 104041 | 32277 | 3913 | 618 | 112 | 60400 | 6720 | 17 | 60 | 0.28 | < 1 | 0.02 | -0.02 | 10.2 | 0.008 | 0.019 |
| 15 | NB-3 | 5.47 | 238 | 102046 | 32129 | 3920 | 629 | 109 | 58800 | 6460 | 17 | 54 | 0.30 | < 1 | 0.02 | -0.01 | 10.1 | 0.007 | 0.023 |
| 16 | JP-5 | 3.33 | 523 | 49512 | 14988 | 1978 | 183 | 323 | 27600 | 4440 | 0 | 104 | 0.45 | 5.6 | 0.02 | -0.02 | 4.7 | 0.014 | 0.026 |
| 17 | JP-2 | 3.49 | 394 | 48276 | 14914 | 1954 | 157 | 361 | 26600 | 4290 | 0 | 102 | 0.52 | 5.9 | 0.02 | 0.00 | 4.6 | 0.019 | 0.029 |
| 18 | JP-4 | 3.57 | 307 | 49628 | 15285 | 1990 | 157 | 376 | 27400 | 4420 | 0 | 109 | 0.34 | 6.3 | 0.02 | -0.01 | 4.7 | 0.021 | 0.027 |
| 19 | JP-3 | 3.61 | 505 | 42284 | 13133 | 1694 | 138 | 339 | 23200 | 3780 | 0 | 93 | 0.21 | 4.5 | 0.02 | 0.00 | 4.1 | 0.021 | 0.026 |
| 20 | NB-4 | 5.1 | 251 | 89339 | 28938 | 3359 | 576 | 97 | 51000 | 5370 | 4 | 52 | 0.25 | < 1 | 0.02 | 0.01 | 9.5 | 0.006 | 0.045 |
| 21 | NB-5 | 5.9 | 232 | 100972 | 31906 | 3739 | 583 | 115 | 58200 | 6430 | 26 | 64 | 0.31 | < 1 | 0.02 | -0.01 | 9.7 | 0.007 | 0.018 |
| 22 | Bore Pump A | 3.64 | 300 | 48215 | 15508 | 2135 | 386 | 226 | 25800 | 4160 | 0 | 97 | 0.32 | 4.5 | 0.02 | 0.04 | 6.4 | 0.007 | 0.033 |

All analyses in mg/L except Eh (in mV) and Au (in µg/L)

Abbreviations

nd - not determined

.a - ASV

.al - alkalinity titration

.i - ICP-AES

.ic - ion chromatography

.m - ICP-MS

.pm - phospho-molybdate method

| | Al.i | Si.i | Sc.n | Ti.i | Cr.i | Mn.i | Fe.i | Co.i | Ni.i | Cu.a | Zn.i | Ga.m | Y.m | Mo.m | Ag.m | Cd.a | Sn.m | La.m | Ce.m | Pr.m |
|----|------|------|--------|--------|--------|------|------|------|------|--------|------|-------|-------|-------|-------|--------|-------|-------|--------|--------|
| 1 | 0 | 3.6 | <0.001 | nd | 0.004 | 0.14 | 0.26 | 0 | 0.01 | 0.019 | 0.04 | 0.013 | 0.008 | 0.014 | 0.004 | 0.003 | 0.004 | 0.001 | 0.001 | 0.0002 |
| 2 | 9.3 | 4.8 | 0.002 | nd | 0.004 | 6.7 | 0.05 | 0.39 | 0.62 | 0.074 | 0 | 0.052 | 0.46 | 0.014 | 0.004 | <0.002 | 0.003 | 0.76 | 1.72 | 0.19 |
| 3 | 28 | 9.4 | 0.002 | nd | 0.005 | 2.5 | 7.7 | 0.22 | 0.60 | 0.044 | 0.05 | 0.088 | 0.80 | 0.009 | 0.004 | <0.002 | 0.002 | 1.96 | 3.16 | 0.48 |
| 4 | 2.7 | 3.3 | <0.001 | nd | 0.002 | 3.5 | 1.06 | 0.19 | 0.60 | 0.122 | 0.06 | 0.020 | 0.38 | 0.007 | 0.004 | 0.004 | 0.004 | 0.34 | 0.09 | 0.07 |
| 5 | 3.8 | 2.2 | <0.001 | nd | 0.007 | 4.6 | 1.25 | 0.24 | 0.59 | 0.056 | 0.17 | 0.023 | 0.45 | 0.007 | 0.002 | <0.002 | 0.003 | 0.41 | 0.40 | 0.08 |
| 6 | 2.7 | 2.1 | <0.001 | nd | <0.002 | 5.6 | 1.35 | 0.25 | 0.55 | 0.090 | 0.14 | 0.029 | 0.56 | 0.008 | 0.005 | 0.010 | 0.005 | 0.48 | 0.53 | 0.07 |
| 7 | 2.6 | 2.2 | <0.001 | nd | <0.002 | 5.5 | 1.55 | 0.28 | 0.56 | 0.202 | 0.12 | 0.021 | 0.44 | 0.006 | 0.003 | <0.002 | 0.003 | 0.28 | 0.24 | 0.06 |
| 8 | 24 | 16.2 | 0.004 | nd | 0.032 | 0.09 | 0.12 | 0.09 | 0.24 | 0.042 | 0.06 | 0.011 | 0.11 | 0.006 | 0.002 | 0.008 | 0.006 | 0.70 | 0.17 | 0.02 |
| 9 | 0.54 | 6.2 | <0.001 | nd | <0.002 | 1.4 | 3.9 | 0.18 | 0.12 | 0.008 | 0.03 | 0.008 | 0.10 | 0.006 | 0.002 | 0.009 | 0.004 | 0.56 | 0.06 | 0.01 |
| 10 | 64 | 14.9 | 0.004 | nd | 0.026 | 0.59 | 3.3 | 0.16 | 0.40 | 0.066 | 0.18 | 0.011 | 0.33 | 0.007 | 0.003 | 0.007 | 0.004 | 0.33 | 0.69 | 0.08 |
| 11 | 0.09 | 12.1 | <0.001 | nd | 0.002 | 0.18 | 8.3 | 0 | 0.03 | 0 | 0 | 0.007 | 0.003 | 0.012 | 0.004 | <0.002 | 0.001 | 0.001 | 0.003 | 0.0004 |
| 12 | 0.04 | 8.5 | <0.001 | nd | <0.002 | 0.65 | 0.21 | 0.01 | 0.05 | 0 | 0 | 0.008 | 0.001 | 0.032 | 0.005 | <0.002 | 0.003 | 0.001 | 0.0004 | 0.0001 |
| 13 | 0.60 | 4.9 | <0.001 | <0.002 | <0.002 | 6.0 | 3.6 | 0.23 | 0.43 | 0.030 | 0.13 | nd | 0.37 | nd | nd | <0.002 | 0.000 | 0.19 | 0.42 | 0.04 |
| 14 | 0.61 | 5.3 | <0.001 | <0.002 | <0.002 | 5.5 | 2.2 | 0.22 | 0.42 | 0.014 | 0.11 | nd | 0.39 | nd | nd | <0.002 | 0.000 | 0.14 | 0.32 | 0.03 |
| 15 | 0.50 | 5.4 | <0.001 | <0.002 | <0.002 | 5.6 | 2.2 | 0.23 | 0.43 | 0.019 | 0.11 | nd | 0.41 | nd | nd | <0.002 | 0.000 | 0.13 | 0.77 | 0.02 |
| 16 | 75 | 44 | 0.001 | <0.002 | 0.031 | 0.63 | 2.2 | 0.10 | 0.42 | <0.005 | 0.08 | nd | 0.36 | nd | nd | <0.002 | 0.057 | 0.41 | 1.02 | 0.10 |
| 17 | 62 | 43 | 0.001 | <0.002 | 0.046 | 0.82 | 2.8 | 0.10 | 0.45 | <0.005 | 0.08 | nd | 0.42 | nd | nd | <0.002 | 0.000 | 0.53 | 1.15 | 0.13 |
| 18 | 55 | 43 | 0.001 | <0.002 | 0.028 | 0.89 | 0.76 | 0.11 | 0.46 | <0.005 | 0.08 | nd | 0.45 | nd | nd | <0.002 | 0.000 | 0.66 | 0.95 | 0.16 |
| 19 | 44 | 35 | 0.001 | <0.002 | 0.007 | 1.1 | 0.15 | 0.09 | 0.38 | 0.020 | 0.07 | nd | 0.33 | nd | nd | <0.002 | 0.005 | 0.45 | 0.52 | 0.11 |
| 20 | 2.3 | 6.0 | <0.001 | <0.002 | <0.002 | 6.9 | 2.5 | 0.32 | 0.57 | 0.065 | 0.14 | nd | 0.61 | nd | nd | <0.002 | 0.000 | 0.34 | 0.34 | 0.06 |
| 21 | 0.20 | 5.6 | <0.001 | <0.002 | <0.002 | 5.0 | 1.5 | 0.22 | 0.41 | 0.040 | 0.10 | nd | 0.44 | nd | nd | <0.002 | 0.000 | 0.17 | 0.35 | 0.03 |
| 22 | 63 | 26 | <0.001 | <0.002 | 0.029 | 1.7 | 14.2 | 0.12 | 0.04 | 0.023 | 0.28 | 0.00 | 0.06 | 0.001 | 0.002 | 0.004 | 0.008 | 0.13 | 0.26 | 0.03 |

| | Nd.m | Sm.m | Eu.m | Gd.m | Tb.m | Dy.m | Ho.m | Er.m | Tm.m | Yb.m | Lu.m | W.m | Au.n (µg/L) | Hg.m | Tl.m | Pb.p | Bi.m | Th.m | U.m |
|----|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|-------|----------------|-------|--------|------|---------|--------|-------|
| 1 | 0.0006 | 0.0003 | 0.0001 | 0.0004 | 0.0000 | 0.0004 | 0.0001 | 0.0002 | 0.0000 | 0.0003 | 0.0000 | 0.016 | 0.005 | 0.005 | 0.0001 | 0.06 | <0.0001 | 0.0004 | 0.012 |
| 2 | 0.34 | 0.096 | 0.021 | 0.089 | 0.010 | 0.044 | 0.007 | 0.020 | 0.003 | 0.016 | 0.002 | 0.039 | 0.133 | 0.004 | 0.0034 | 0.69 | <0.0001 | 0.0003 | 0.046 |
| 3 | 0.88 | 0.132 | 0.050 | 0.108 | 0.022 | 0.086 | 0.015 | 0.035 | 0.005 | 0.026 | 0.004 | 0.068 | 0.037 | 0.004 | 0.0016 | 0.41 | <0.0001 | 0.0003 | 0.050 |
| 4 | 0.13 | 0.044 | 0.012 | 0.041 | 0.006 | 0.031 | 0.005 | 0.015 | 0.002 | 0.011 | 0.002 | 0.028 | 0.040 | 0.003 | 0.0007 | 0.02 | <0.0001 | 0.0001 | 0.004 |
| 5 | 0.15 | 0.044 | 0.012 | 0.046 | 0.006 | 0.033 | 0.006 | 0.016 | 0.002 | 0.012 | 0.002 | 0.038 | 0.009 | 0.003 | 0.0011 | 0.11 | <0.0001 | 0.0002 | 0.009 |
| 6 | 0.22 | 0.072 | 0.018 | 0.064 | 0.009 | 0.049 | 0.009 | 0.022 | 0.003 | 0.018 | 0.003 | 0.038 | 0 | 0.002 | 0.0017 | 0.04 | <0.0001 | 0.0002 | 0.012 |
| 7 | 0.12 | 0.040 | 0.011 | 0.038 | 0.006 | 0.030 | 0.006 | 0.016 | 0.002 | 0.011 | 0.002 | 0.032 | 0 | 0.003 | 0.0006 | 0.02 | <0.0001 | 0.0002 | 0.008 |
| 8 | 0.05 | 0.014 | 0.004 | 0.012 | 0.002 | 0.008 | 0.001 | 0.004 | 0.001 | 0.003 | 0.001 | 0.028 | 0 | 0.002 | 0.0003 | 0.07 | <0.0001 | 0.0002 | 0.014 |
| 9 | 0.02 | 0.005 | 0.002 | 0.007 | 0.001 | 0.005 | 0.001 | 0.002 | 0.000 | 0.002 | 0.000 | 0.015 | 0 | 0.002 | 0.0003 | 0.01 | <0.0001 | 0.0002 | 0.001 |
| 10 | 0.15 | 0.045 | 0.010 | 0.043 | 0.005 | 0.023 | 0.004 | 0.011 | 0.001 | 0.008 | 0.001 | 0.023 | 0 | 0.002 | 0.0009 | 0.23 | <0.0001 | 0.0004 | 0.440 |
| 11 | 0.0010 | 0.0003 | 0.0001 | 0.0003 | 0.0000 | 0.0002 | 0.0000 | 0.0002 | 0.0000 | 0.0001 | 0.0000 | 0.128 | 0 | 0.004 | 0.0001 | 0.01 | <0.0001 | 0.0003 | 0.006 |
| 12 | 0.0004 | 0.0003 | 0.0001 | 0.0001 | 0.0000 | 0.0001 | 0.0000 | 0.0001 | 0.0000 | 0.0001 | 0.0000 | 0.024 | 0.006 | 0.003 | 0.0016 | 0.01 | <0.0001 | 0.0001 | 0.011 |
| 13 | 0.12 | 0.020 | 0.006 | 0.023 | 0.003 | 0.016 | 0.004 | 0.009 | 0.001 | 0.007 | 0.001 | nd | 0.029 | 0.001 | 0.0010 | 0.07 | <0.0001 | 0.0021 | 0.003 |
| 14 | 0.09 | 0.017 | 0.005 | 0.021 | 0.003 | 0.018 | 0.004 | 0.010 | 0.002 | 0.008 | 0.002 | nd | 0.007 | 0.002 | 0.0015 | 0.05 | <0.0001 | 0.0010 | 0.004 |
| 15 | 0.08 | 0.015 | 0.005 | 0.018 | 0.003 | 0.017 | 0.004 | 0.010 | 0.002 | 0.006 | 0.001 | nd | 0.007 | 0.001 | 0.0007 | 0.04 | <0.0001 | 0.0005 | 0.003 |
| 16 | 0.33 | 0.047 | 0.011 | 0.039 | 0.004 | 0.020 | 0.004 | 0.010 | 0.001 | 0.008 | 0.001 | nd | 0.006 | 0.000 | 0.0006 | 0.11 | <0.0001 | 0.0004 | 0.090 |
| 17 | 0.43 | 0.063 | 0.014 | 0.045 | 0.005 | 0.021 | 0.004 | 0.011 | 0.002 | 0.009 | 0.001 | nd | 0.003 | 0.003 | 0.0014 | 0.05 | <0.0001 | 0.0005 | 0.035 |
| 18 | 0.51 | 0.075 | 0.016 | 0.055 | 0.006 | 0.029 | 0.005 | 0.012 | 0.002 | 0.009 | 0.001 | nd | 0.005 | 0.001 | 0.0010 | 0.04 | <0.0001 | 0.0011 | 0.025 |
| 19 | 0.34 | 0.051 | 0.010 | 0.039 | 0.004 | 0.020 | 0.004 | 0.008 | 0.001 | 0.006 | 0.001 | nd | 0.008 | 0.002 | 0.0009 | 0.07 | <0.0001 | 0.0005 | 0.041 |
| 20 | 0.22 | 0.035 | 0.009 | 0.031 | 0.005 | 0.025 | 0.006 | 0.014 | 0.002 | 0.010 | 0.002 | nd | 0.012 | 0.001 | 0.0008 | 0.14 | <0.0001 | 0.0008 | 0.003 |
| 21 | 0.11 | 0.021 | 0.006 | 0.024 | 0.003 | 0.020 | 0.004 | 0.011 | 0.002 | 0.008 | 0.001 | nd | 0.008 | 0.000 | 0.0011 | 0.03 | <0.0001 | 0.0008 | 0.002 |
| 22 | 0.11 | 0.017 | 0.005 | 0.023 | 0.002 | 0.011 | 0.002 | 0.005 | 0.001 | 0.003 | 0.000 | 0.001 | 0.003 | 0.004 | 0.0002 | 0.05 | <0.0001 | 0.0003 | 0.103 |

Appendix 2 - Element/Ion Concentration Plots

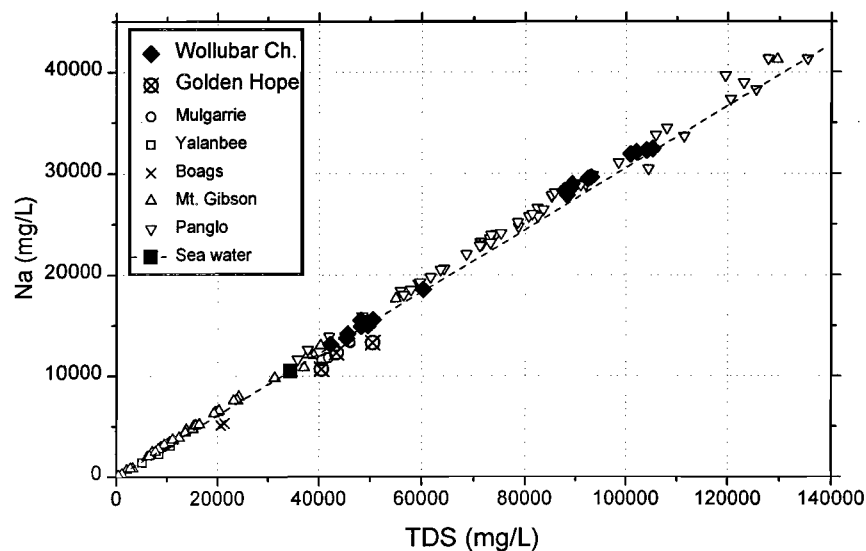


Figure A2.1: Sodium vs. TDS for groundwaters from Wollubar palaeochannel, Golden Hope and other sites.

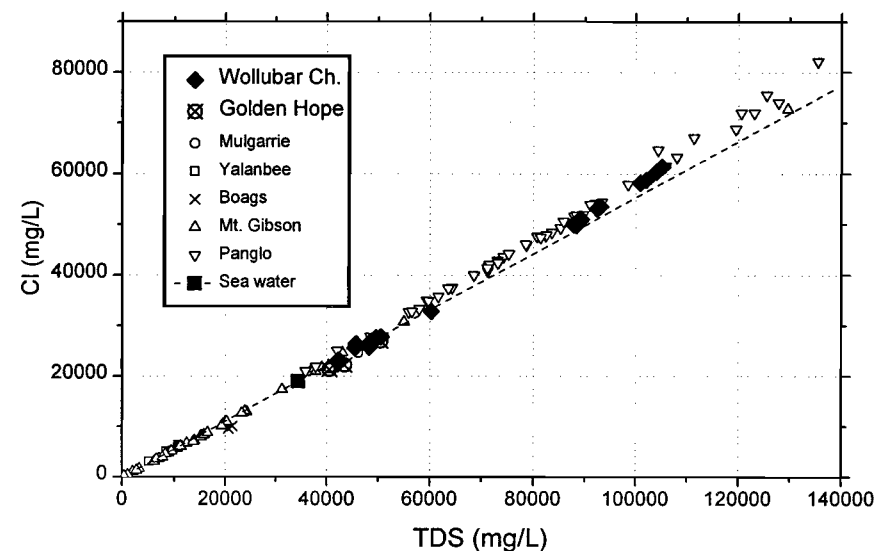


Figure A2.3: Chloride vs. TDS for groundwaters from Wollubar palaeochannel, Golden Hope and other sites.

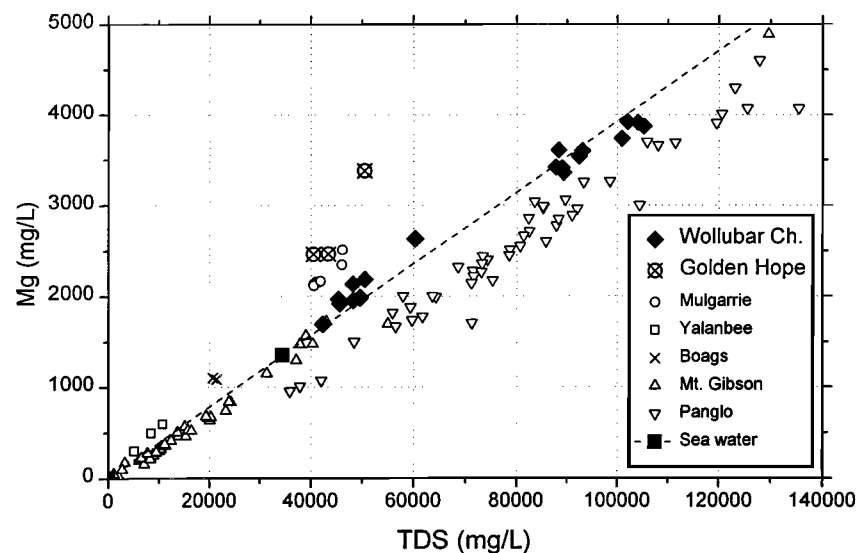


Figure A2.2: Magnesium vs. TDS for groundwaters from Wollubar palaeochannel, Golden Hope and other sites.

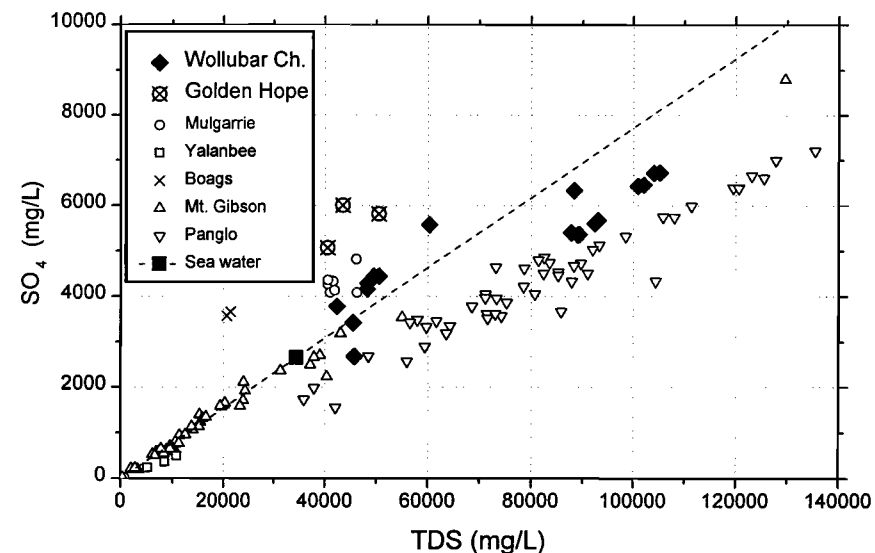


Figure A2.4: Sulphate vs. TDS for groundwaters from Wollubar palaeochannel, Golden Hope and other sites.

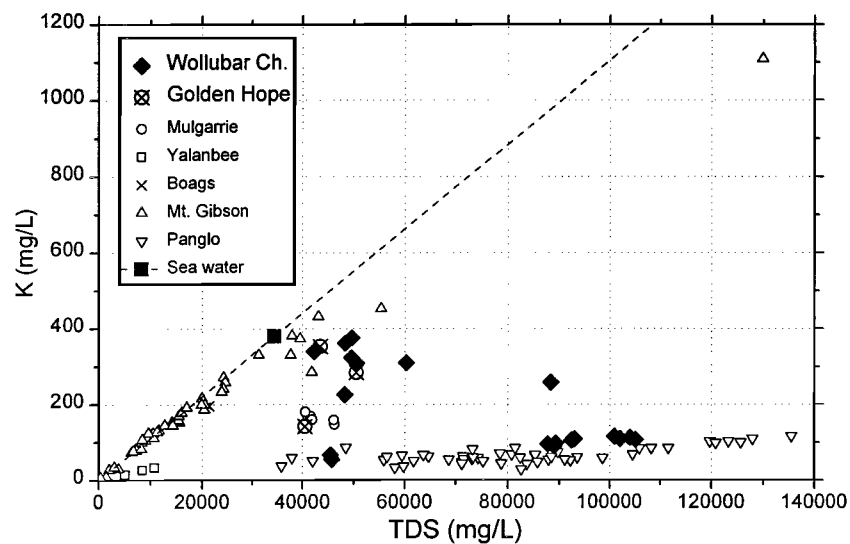


Figure A2.5: Potassium vs. TDS for groundwaters from Wollubar palaeochannel, Golden Hope and other sites.

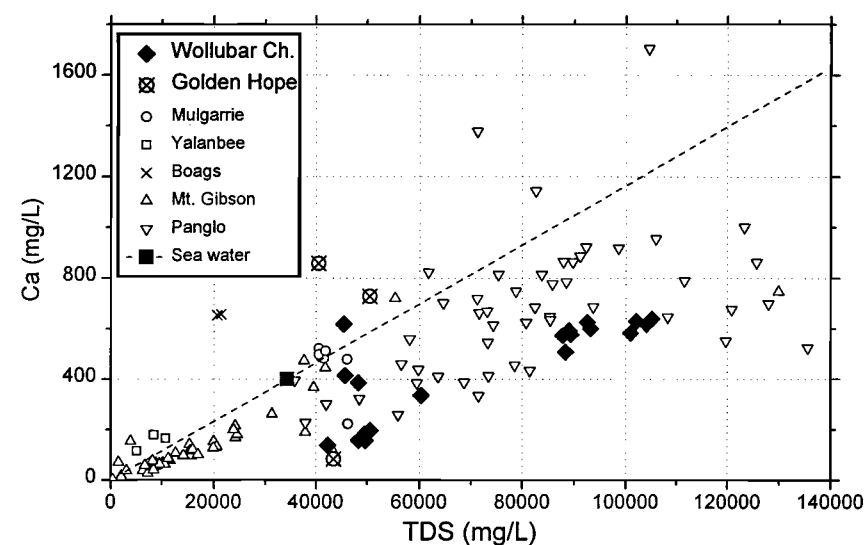


Figure A2.7: Calcium vs. TDS for groundwaters from Wollubar palaeochannel, Golden Hope and other sites.

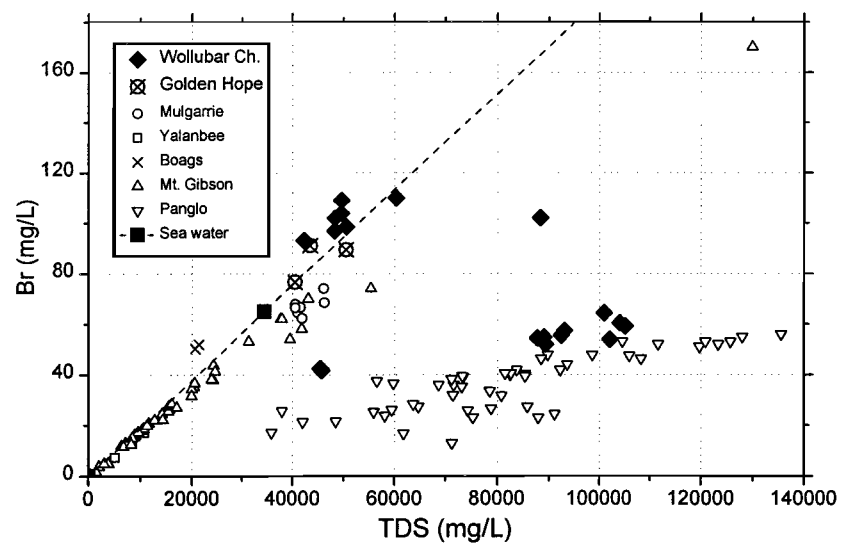


Figure A2.6: Bromine vs. TDS for groundwaters from Wollubar palaeochannel, Golden Hope and other sites.

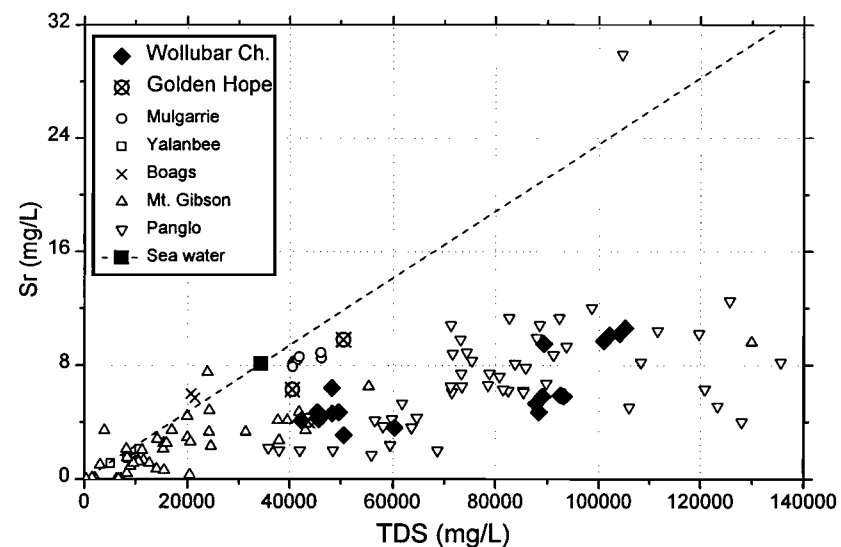


Figure A2.8: Strontium vs. TDS for groundwaters from Wollubar palaeochannel, Golden Hope and other sites.

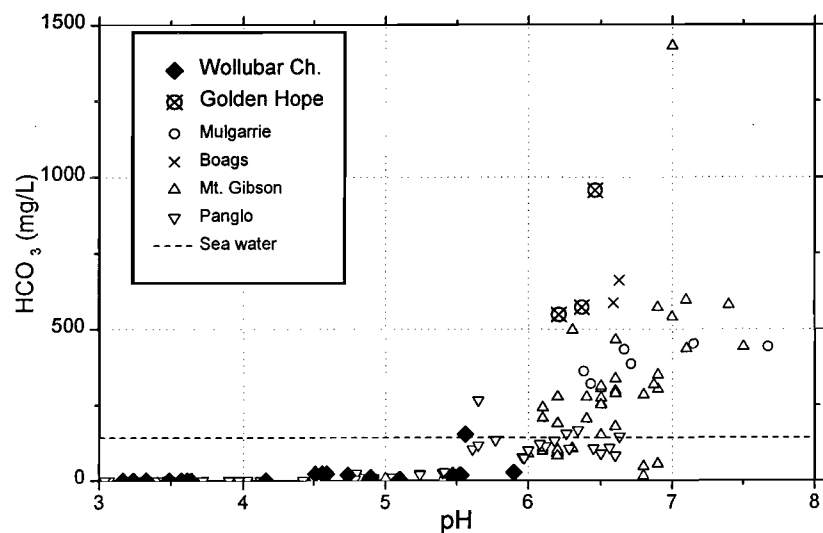


Figure A2.9: Bicarbonate vs. pH for groundwaters from Wollubar palaeochannel, Golden Hope and other sites.

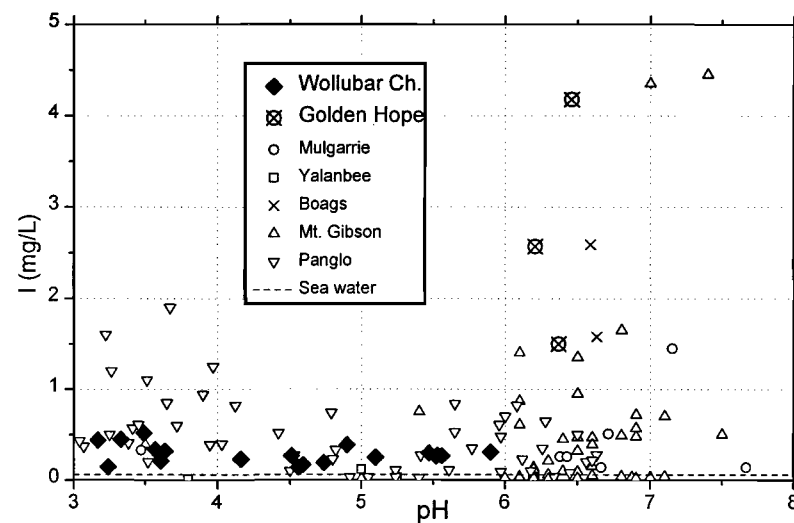


Figure A2.11: Iodide vs. pH for groundwaters from Wollubar palaeochannel, Golden Hope and other sites.

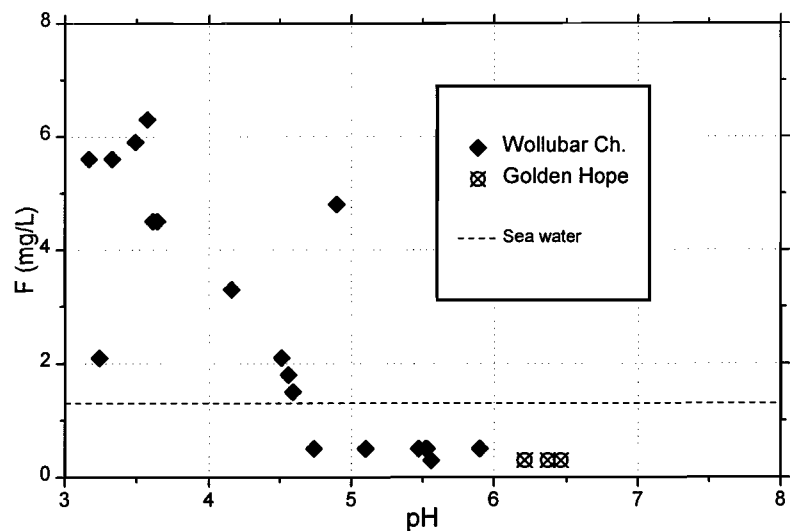


Figure A2.10: Fluoride vs. pH for groundwaters from Wollubar palaeochannel and Golden Hope.

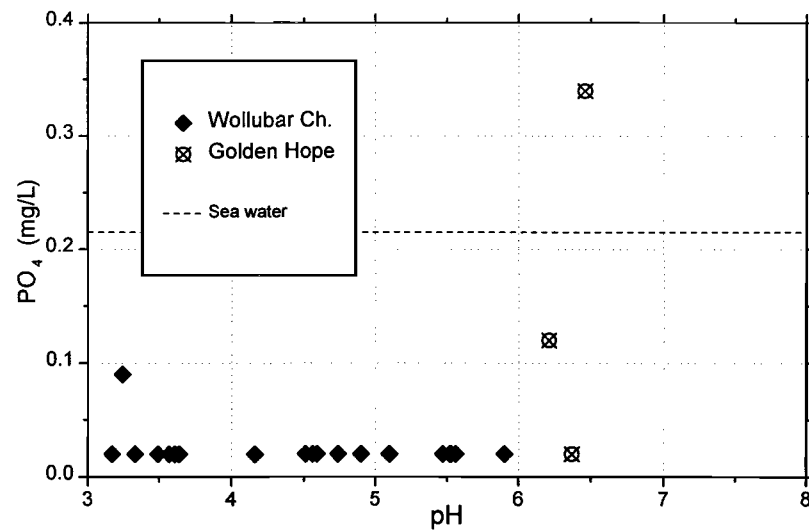


Figure A2.12: Phosphate vs. pH for groundwaters from Wollubar palaeochannel and Golden Hope.

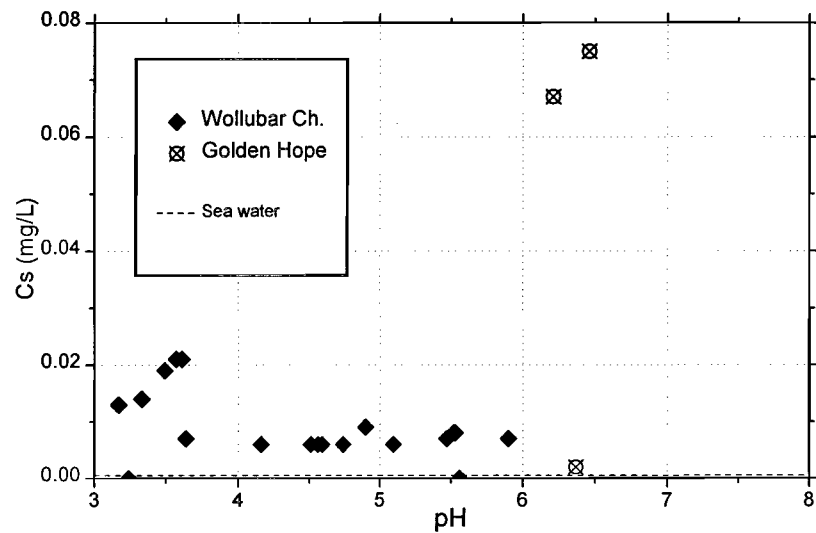


Figure A2.13: Caesium vs. pH for groundwaters from Wollubar palaeochannel and Golden Hope.

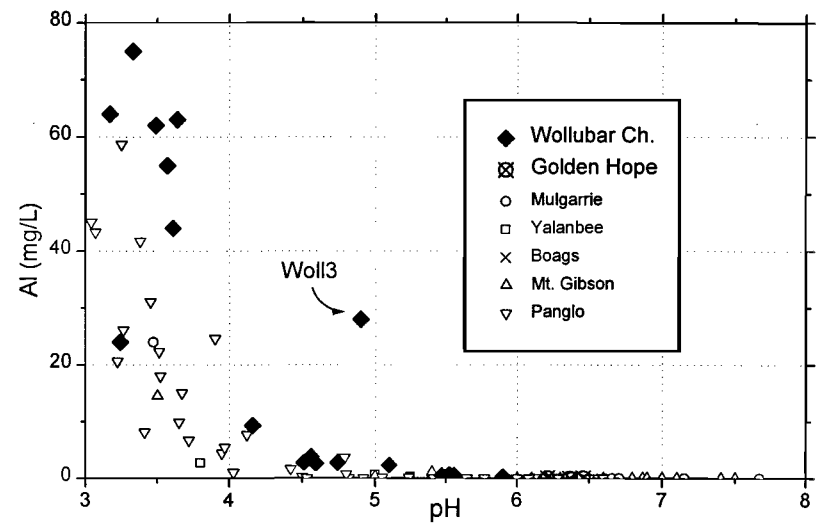


Figure A2.15: Aluminium vs. pH for groundwaters from Wollubar palaeochannel, Golden Hope and other sites.

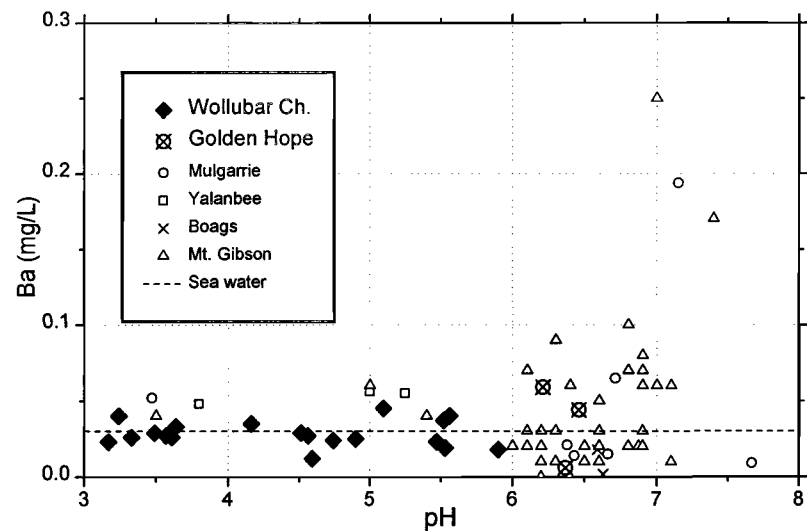


Figure A2.14: Barium vs. pH for groundwaters from Wollubar palaeochannel, Golden Hope and other sites.

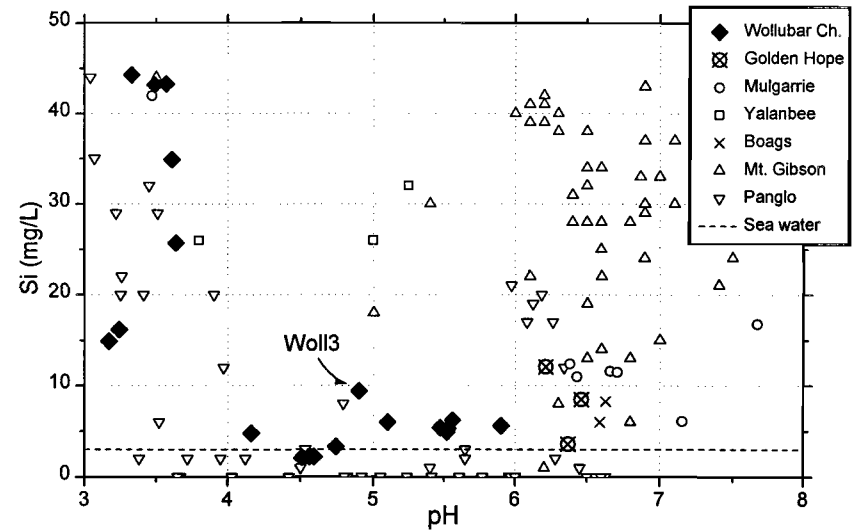


Figure A2.16: Silicon vs. pH for groundwaters from Wollubar palaeochannel, Golden Hope and other sites.

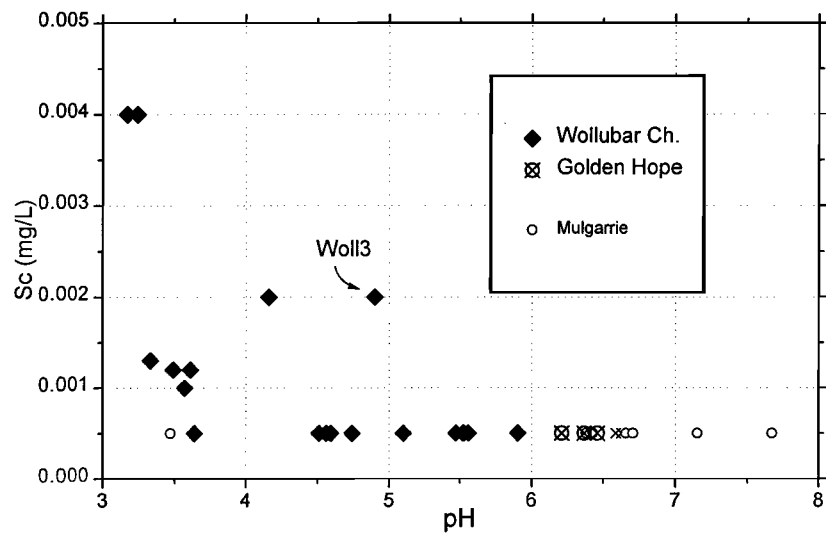


Figure A2.17: Scandium vs. pH for groundwaters from Wollubar palaeodrainage, Golden Hope and other sites.

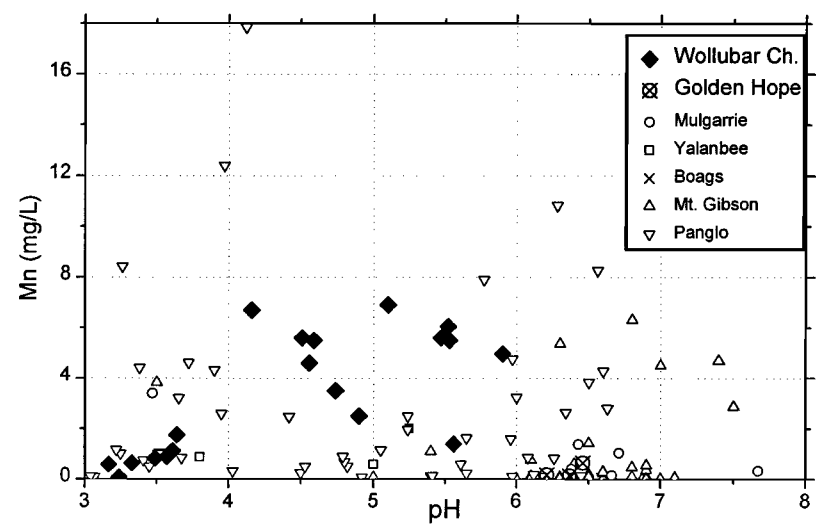


Figure A2.19: Manganese vs. pH for groundwaters from Wollubar palaeodrainage, Golden Hope and other sites.

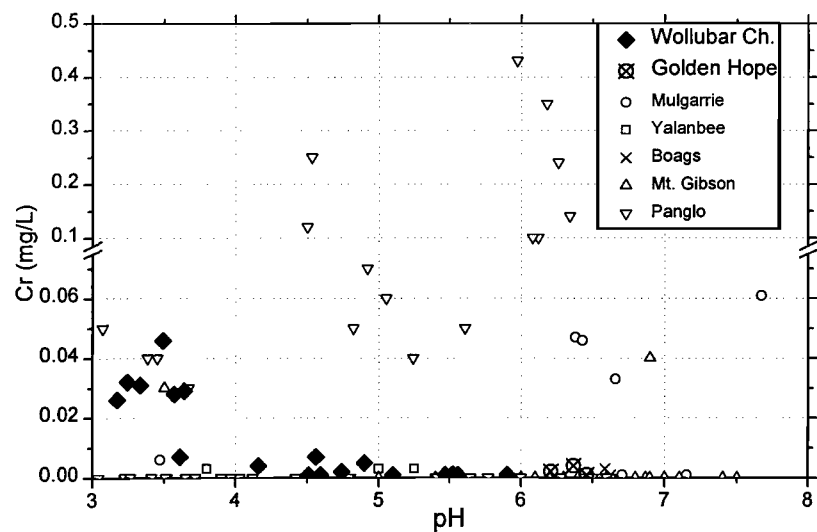


Figure A2.18: Chromium vs. pH for groundwaters from Wollubar palaeodrainage, Golden Hope and other sites.

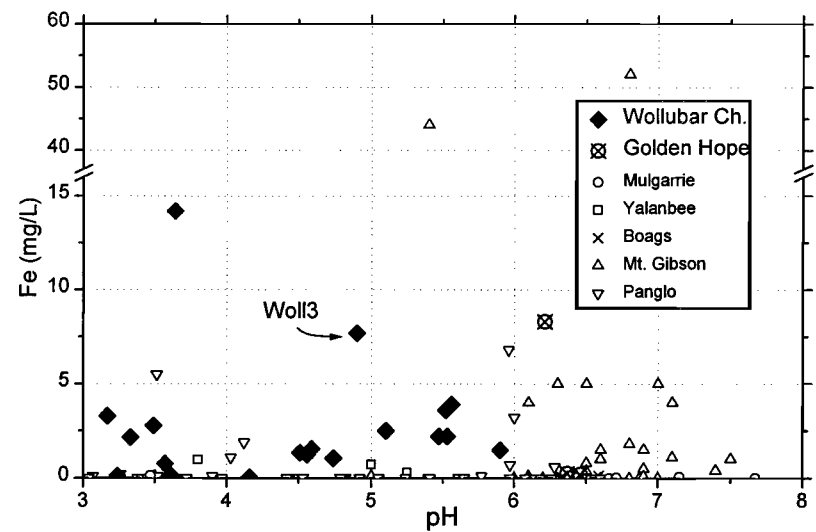


Figure A2.20: Iron vs. pH for groundwaters from Wollubar palaeodrainage, Golden Hope and other sites.

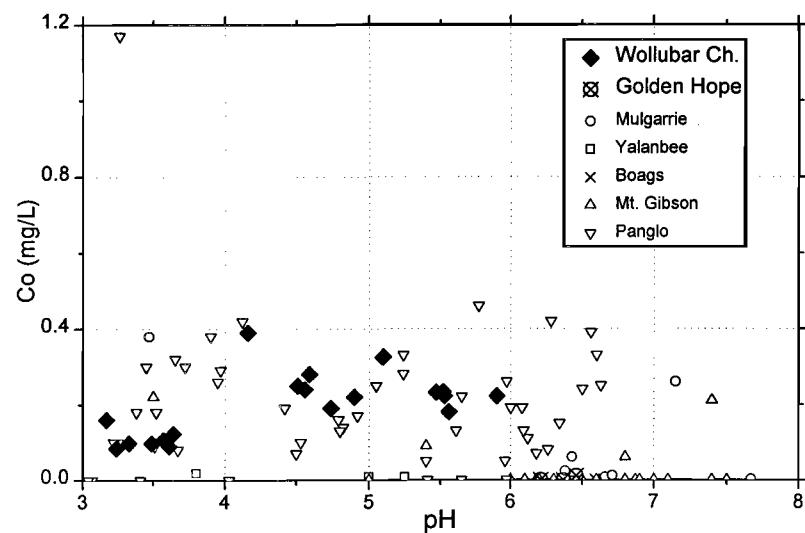


Figure A2.21: Cobalt vs. pH for groundwaters from Wollubar palaeochannel, Golden Hope and other sites.

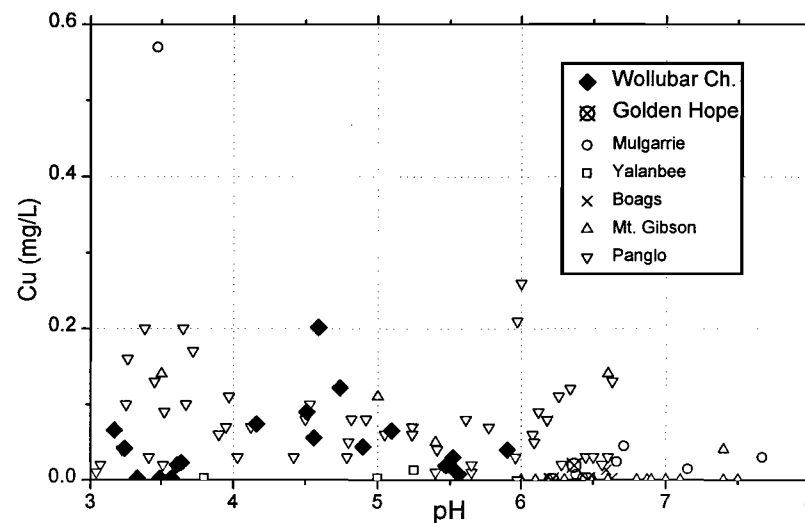


Figure A2.23: Copper vs. pH for groundwaters from Wollubar palaeochannel, Golden Hope and other sites.

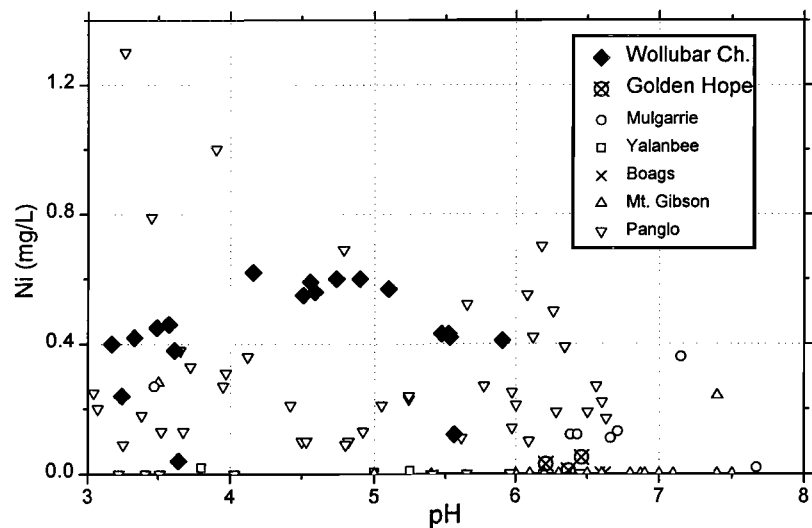


Figure A2.22: Nickel vs. pH for groundwaters from Wollubar palaeochannel, Golden Hope and other sites.

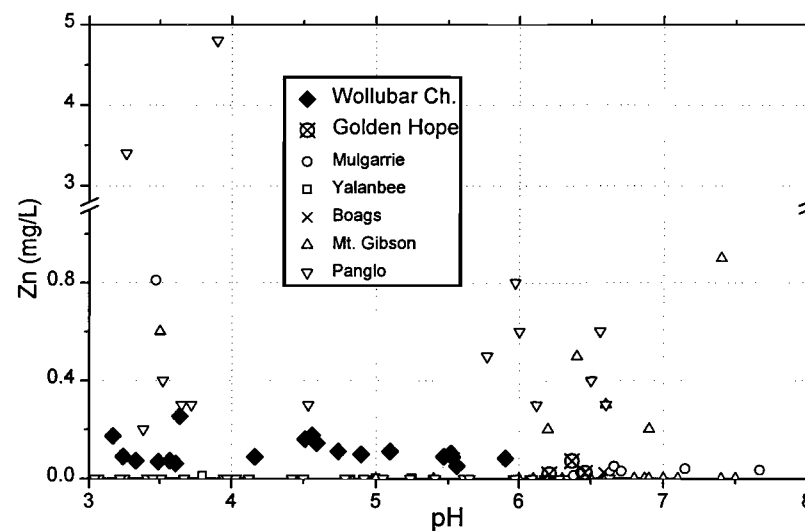


Figure A2.24: Zinc vs. pH for groundwaters from Wollubar palaeochannel, Golden Hope and other sites.

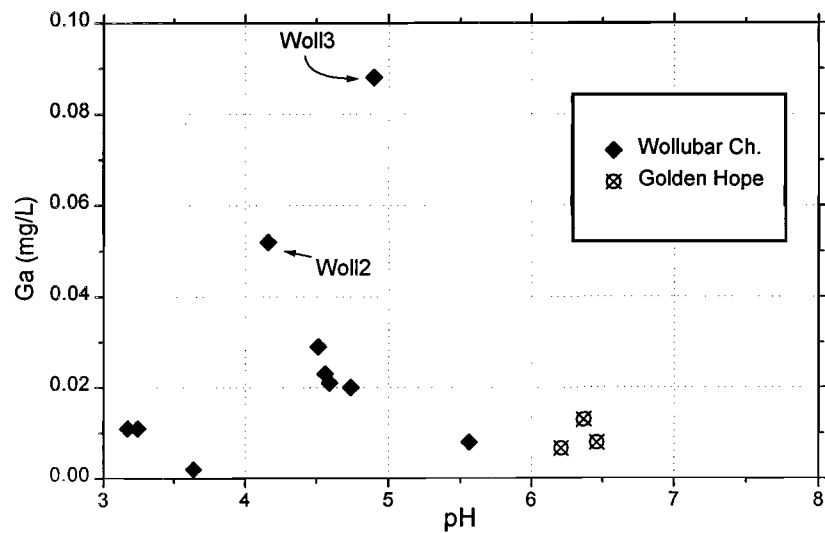


Figure A2.25: Gallium vs. pH for groundwaters from Wollubar palaeochannel and Golden Hope.

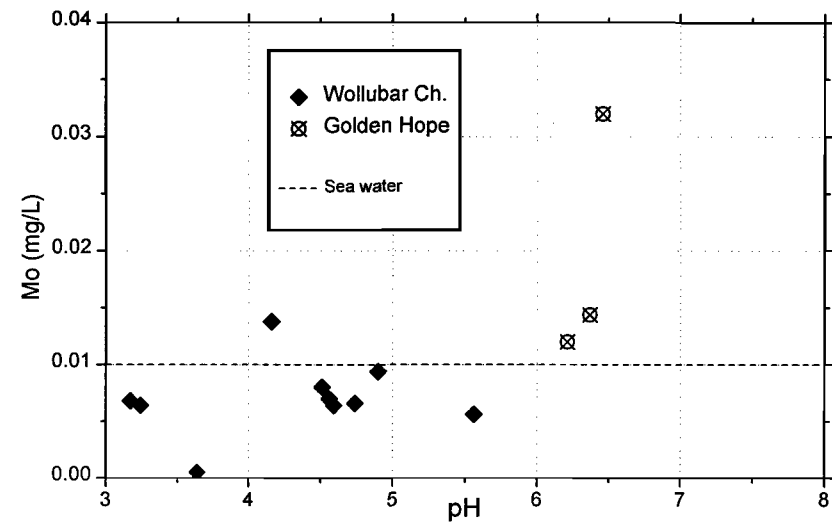


Figure A2.27: Molybdenum vs. pH for groundwaters from Wollubar palaeochannel and Golden Hope.

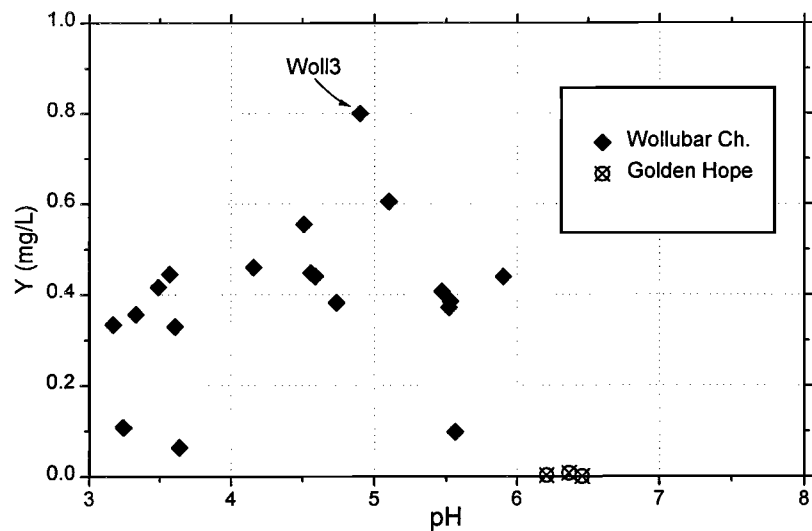


Figure A2.26: Yttrium vs. pH for groundwaters from Wollubar palaeochannel and Golden Hope.

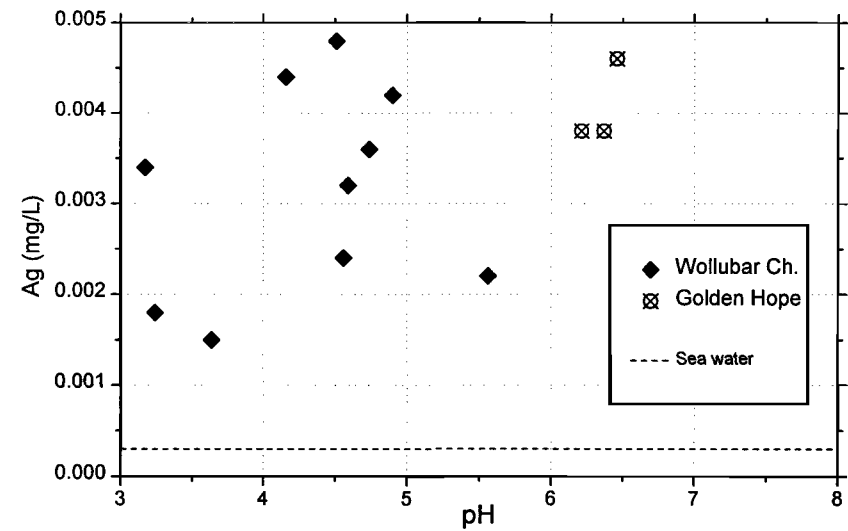


Figure A2.28: Silver vs. pH for groundwaters from Wollubar palaeochannel and Golden Hope.

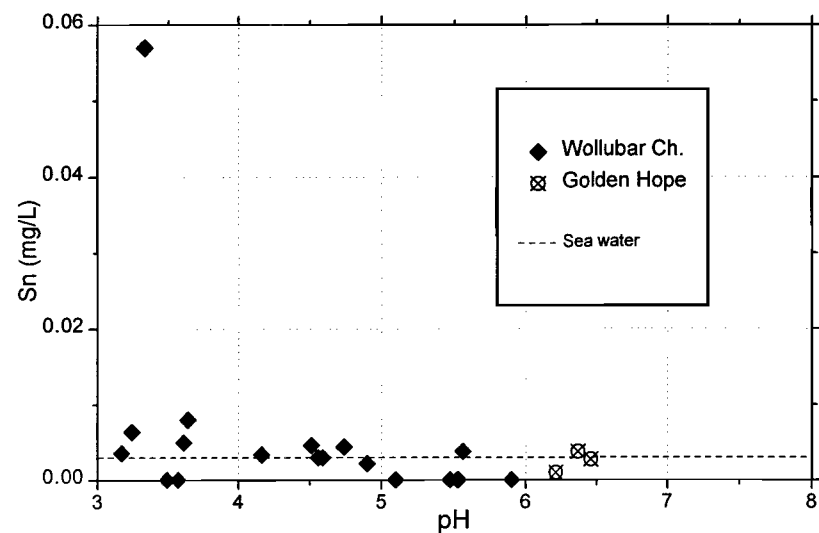


Figure A2.29: Tin vs. pH for groundwaters from Wollubar palaeochannel and Golden Hope.

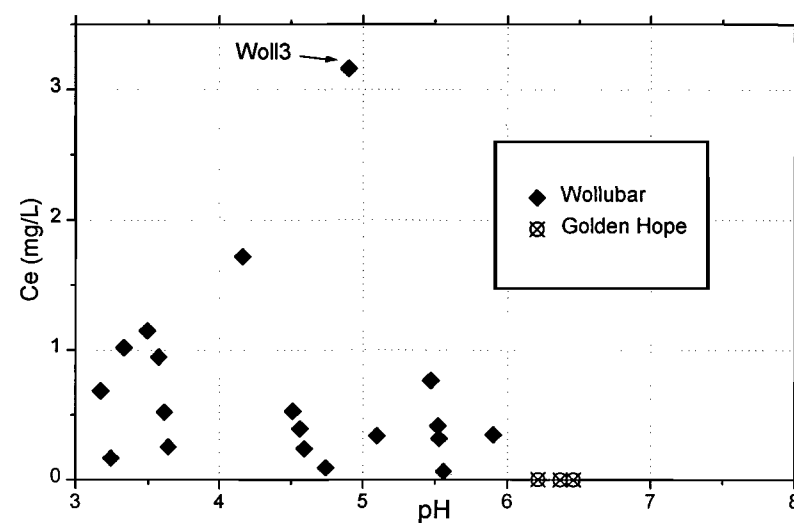


Figure A2.31: Cerium vs. pH for groundwaters from Wollubar palaeochannel and Golden Hope.

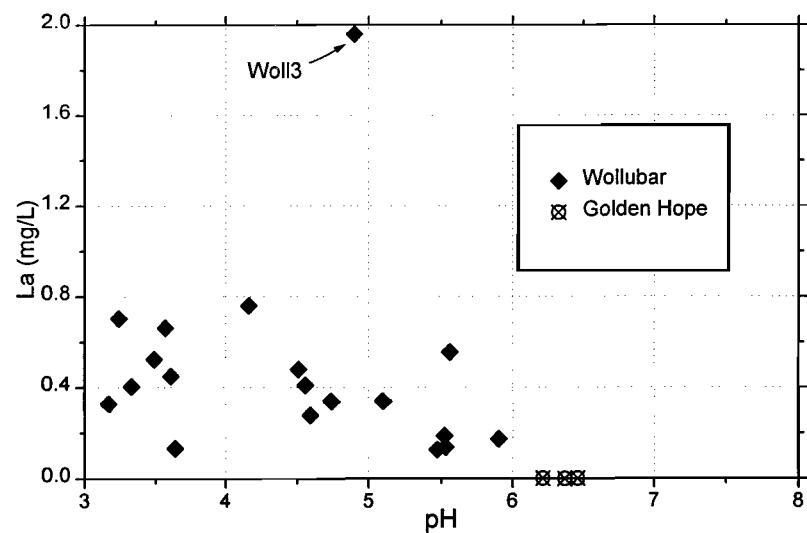


Figure A2.30: Lanthanum vs. pH for groundwaters from Wollubar palaeochannel and Golden Hope.

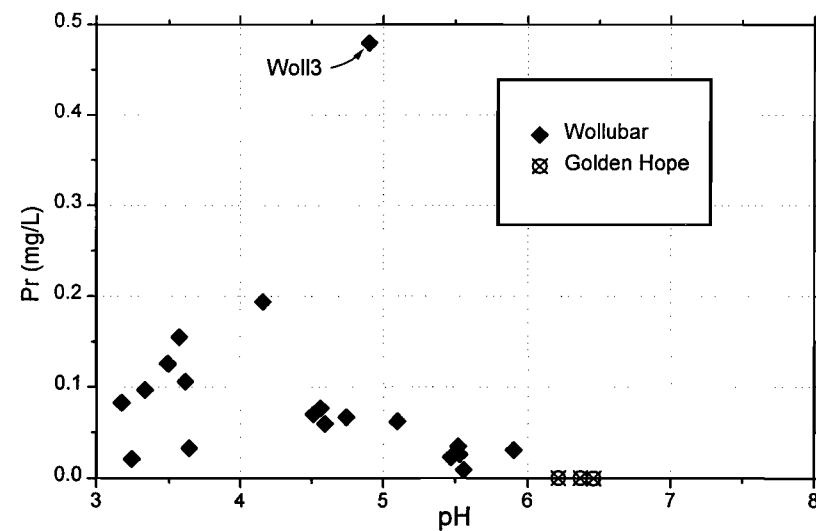


Figure A2.32: Praeseodymium vs. pH for groundwaters from Wollubar palaeochannel and Golden Hope.

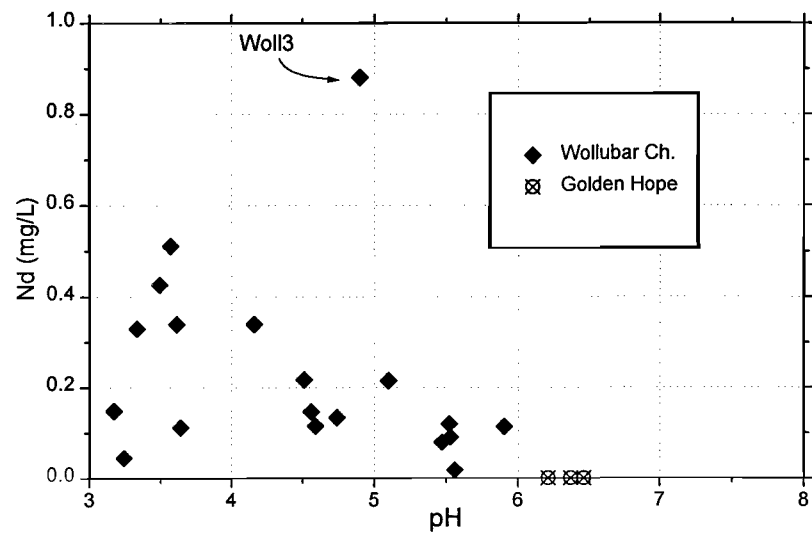


Figure A2.33: Neodymium vs. pH for groundwaters from Wollubar palaeochannel and Golden Hope.

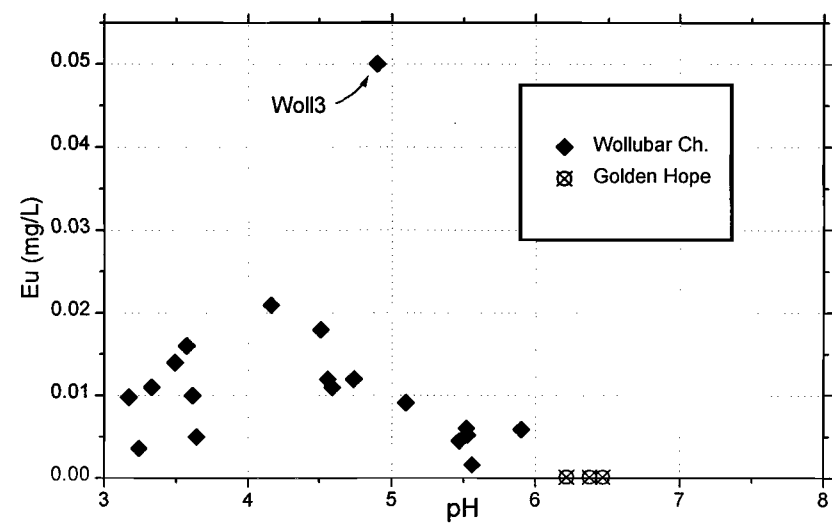


Figure A2.35: Europium vs. pH for groundwaters from Wollubar palaeochannel and Golden Hope.

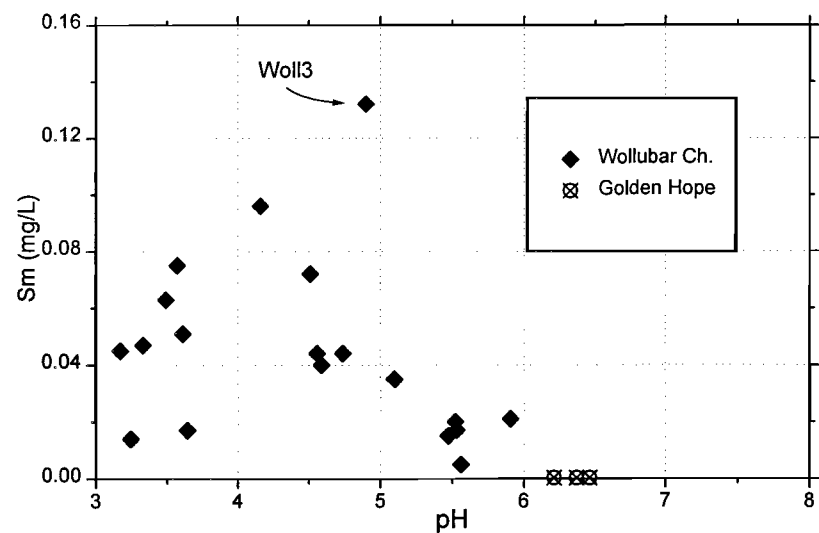


Figure A2.34: Samarium vs. pH for groundwaters from Wollubar palaeochannel and Golden Hope.

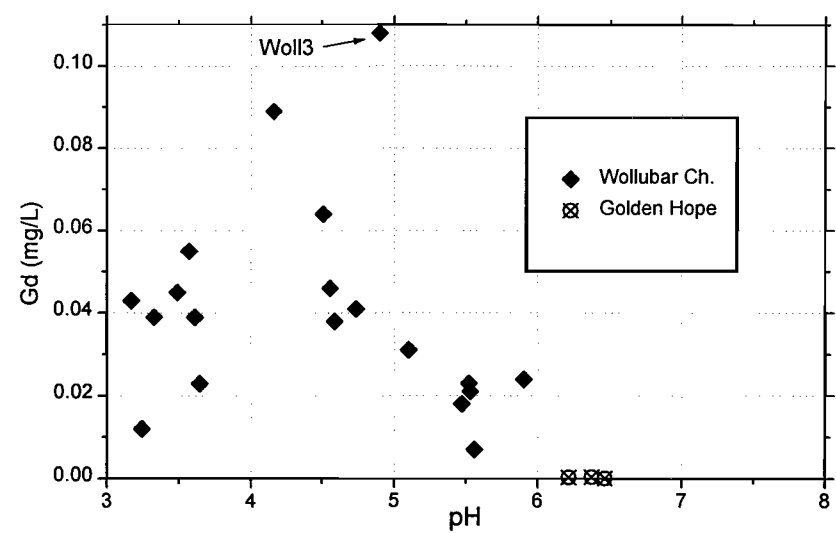


Figure A2.36: Gadolinium vs. pH for groundwaters from Wollubar palaeochannel and Golden Hope.

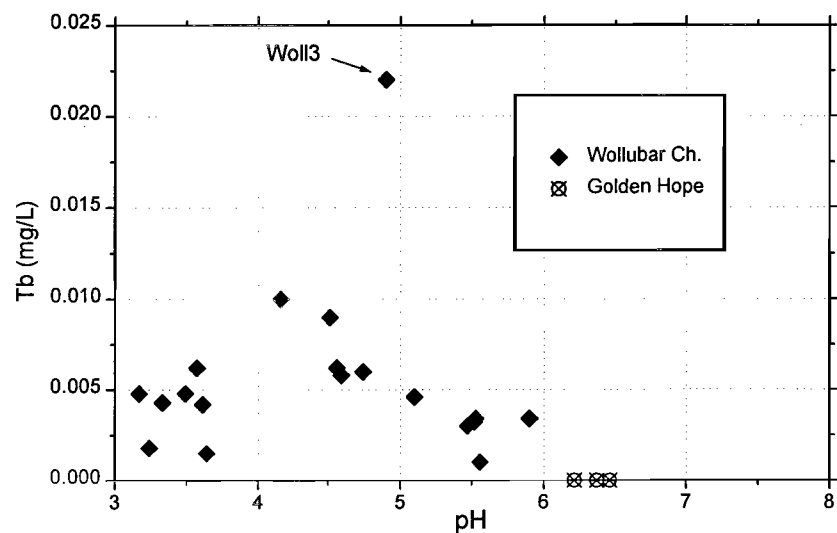


Figure A2.37: Terbium vs. pH for groundwaters from Wollubar palaeochannel and Golden Hope.

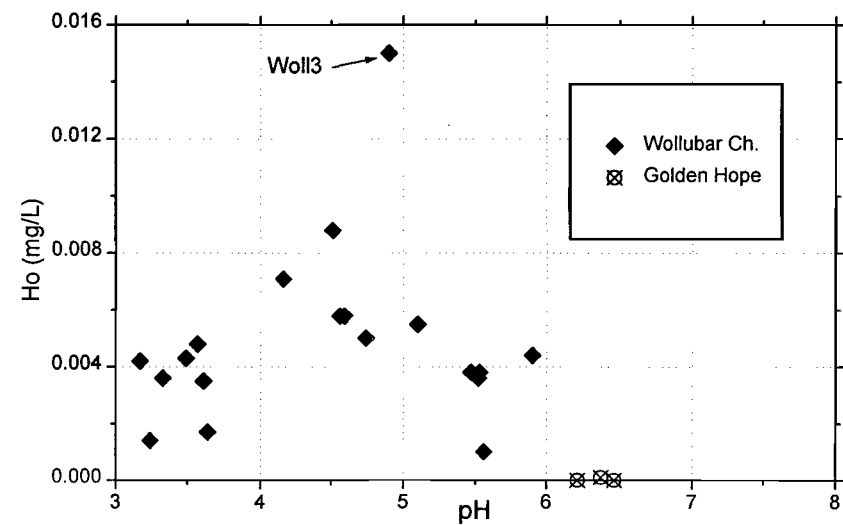


Figure A2.39: Holmium vs. pH for groundwaters from Wollubar palaeochannel and Golden Hope.

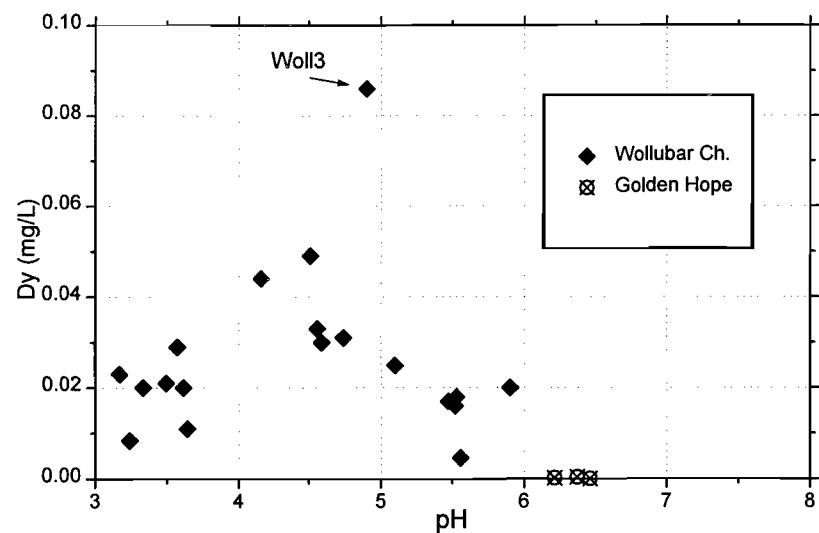


Figure A2.38: Dysprosium vs. pH for groundwaters from Wollubar palaeochannel and Golden Hope.

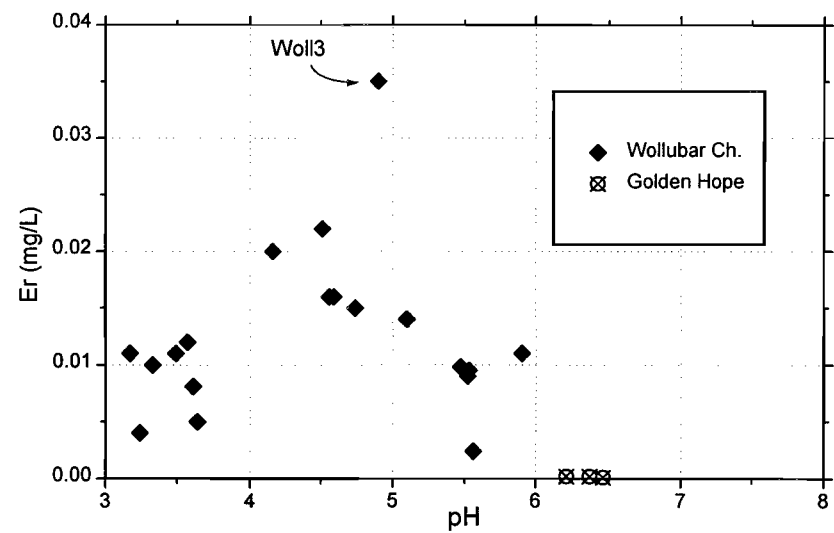


Figure A2.40: Erbium vs. pH for groundwaters from Wollubar palaeochannel and Golden Hope.

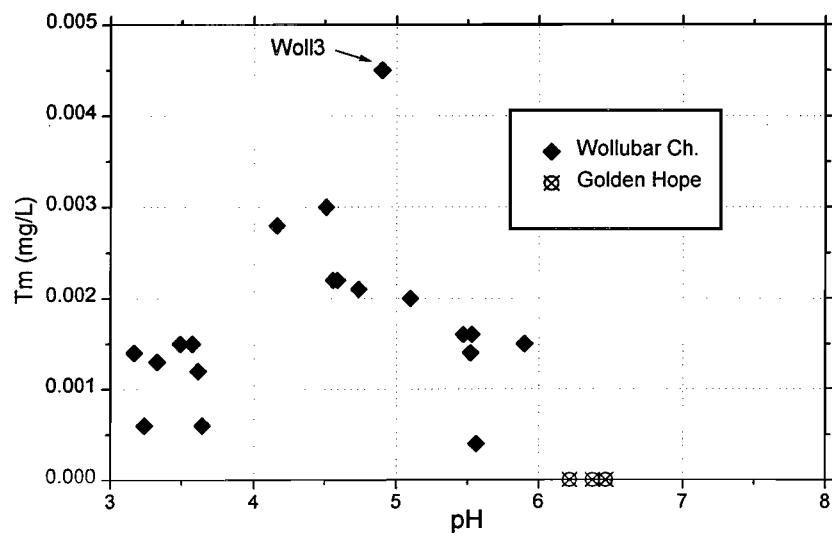


Figure A2.41: Thulium vs. pH for groundwaters from Wollubar palaeochannel and Golden Hope.

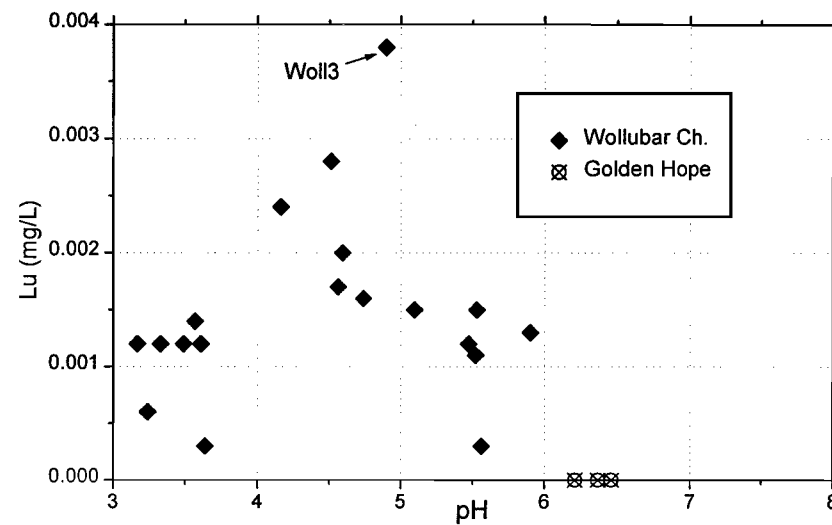


Figure A2.43: Lutetium vs. pH for groundwaters from Wollubar palaeochannel and Golden Hope.

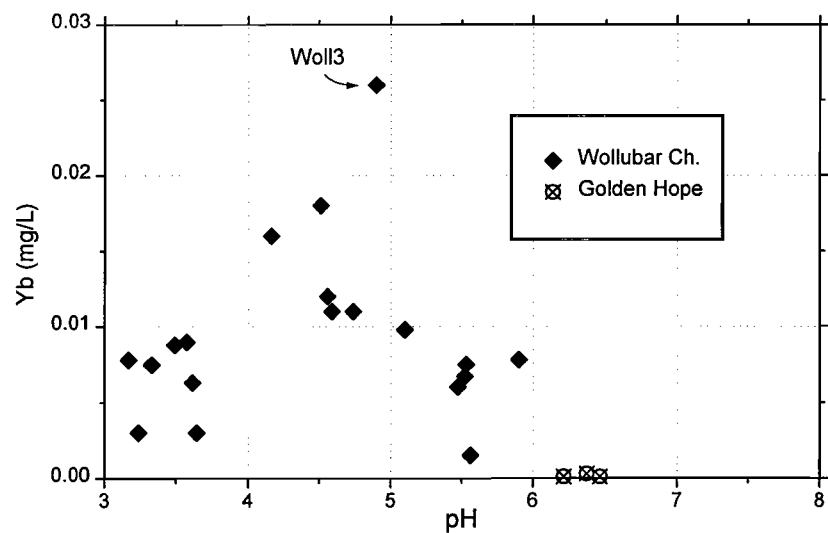


Figure A2.42: Ytterbium vs. pH for groundwaters from Wollubar palaeochannel and Golden Hope.

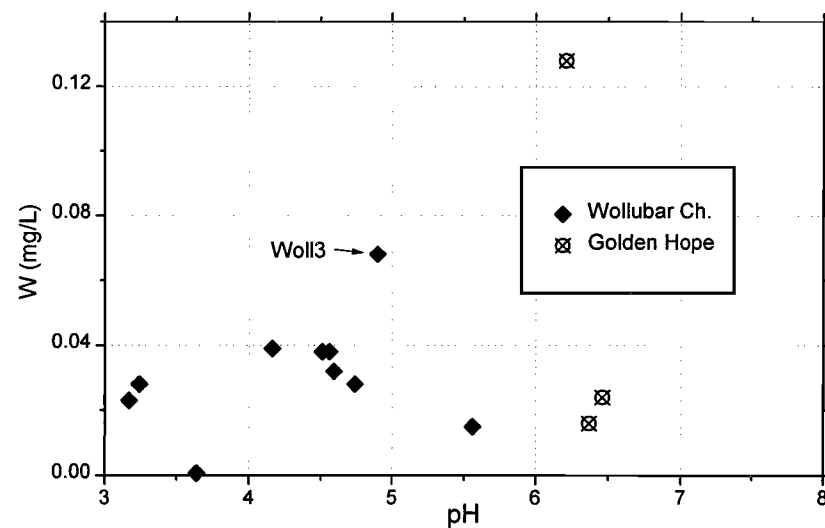


Figure A2.44: Tungsten vs. pH for groundwaters from Wollubar palaeochannel and Golden Hope.

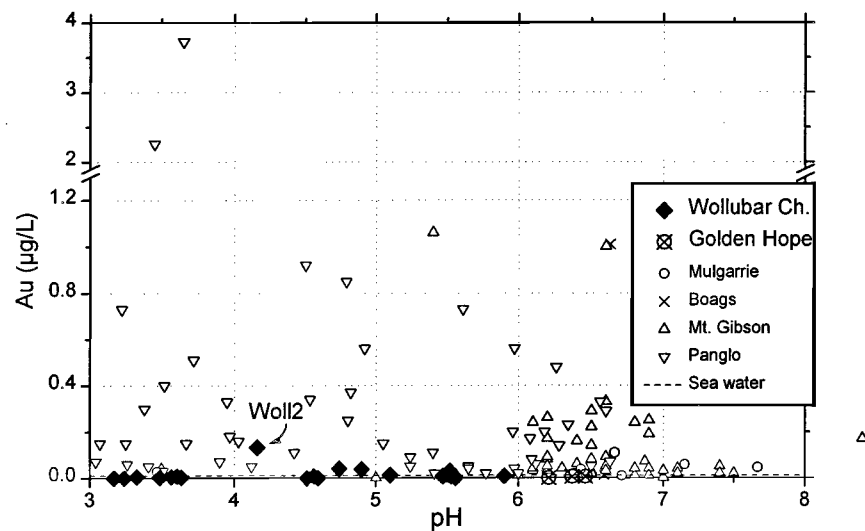


Figure A2.45: Gold vs. pH for groundwaters from Wollubar palaeochannel, Golden Hope and other sites.

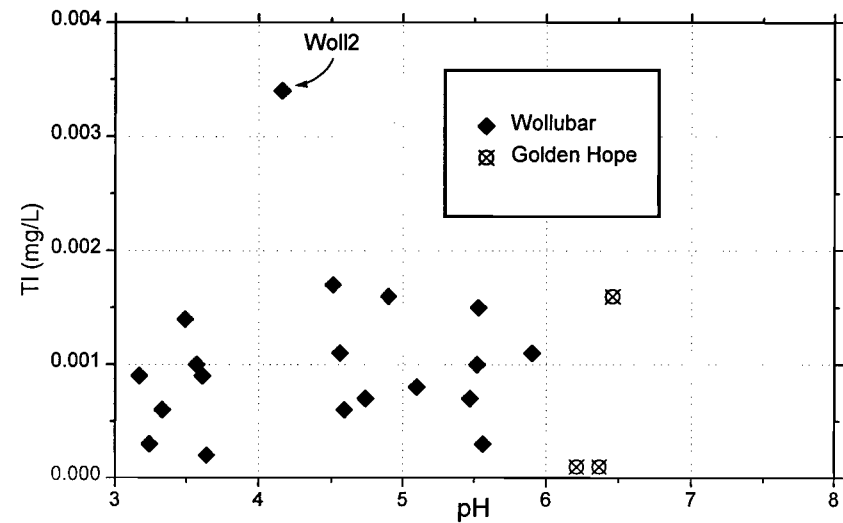


Figure A2.47: Thallium vs. pH for groundwaters from Wollubar palaeochannel and Golden Hope.

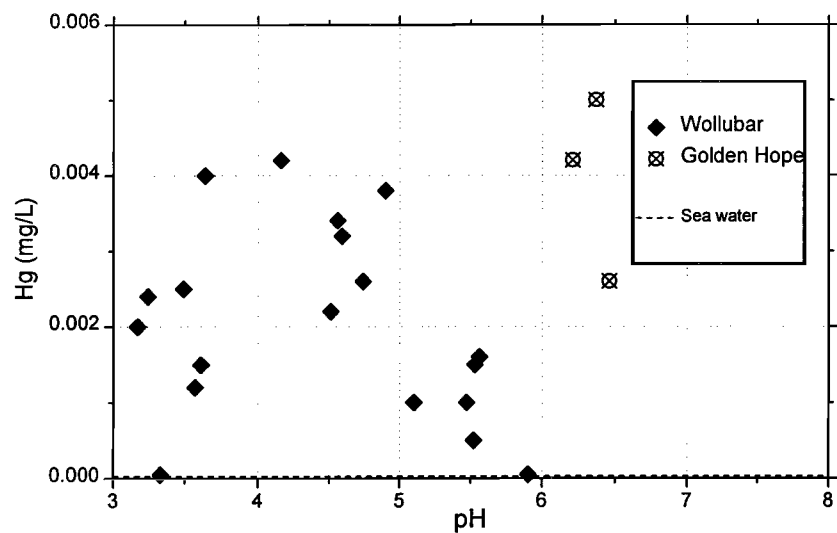


Figure A2.46: Mercury vs. pH for groundwaters from Wollubar palaeochannel and Golden Hope.

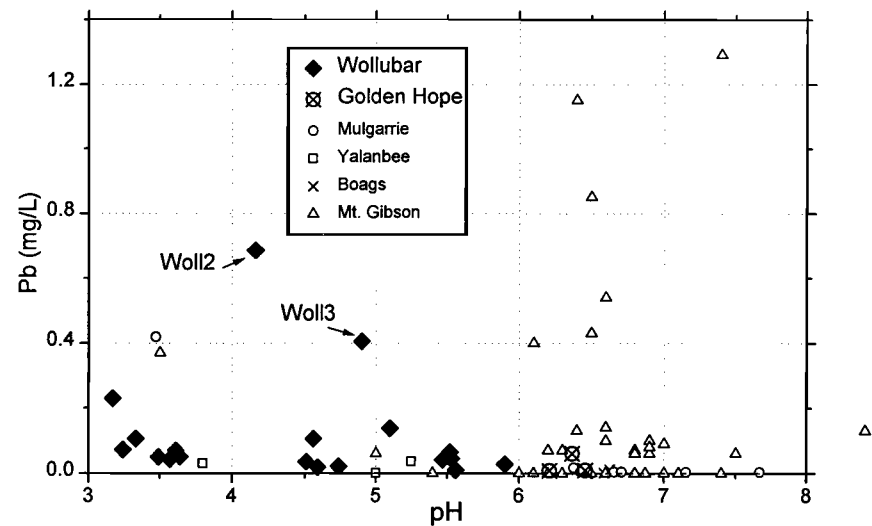


Figure A2.48: Lead vs. pH for groundwaters from Wollubar palaeochannel, Golden Hope and other sites.

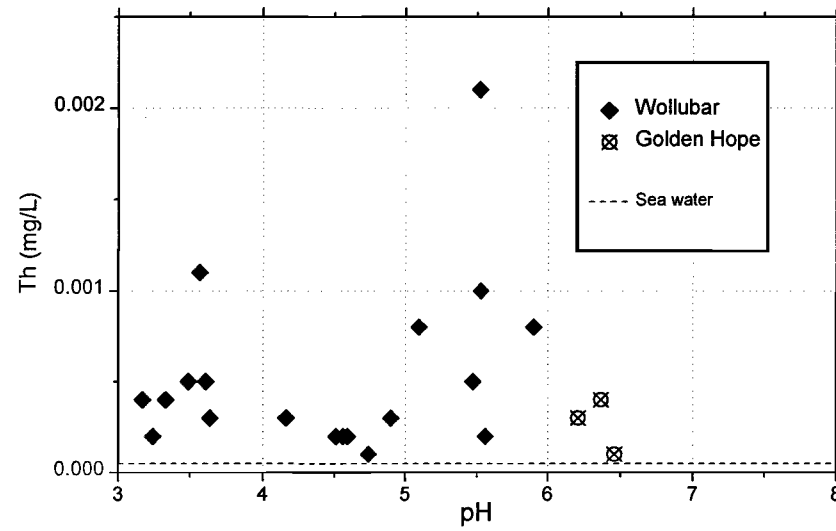


Figure A2.49: Thorium vs. pH for groundwaters from Wollubar palaeochannel and Golden Hope.

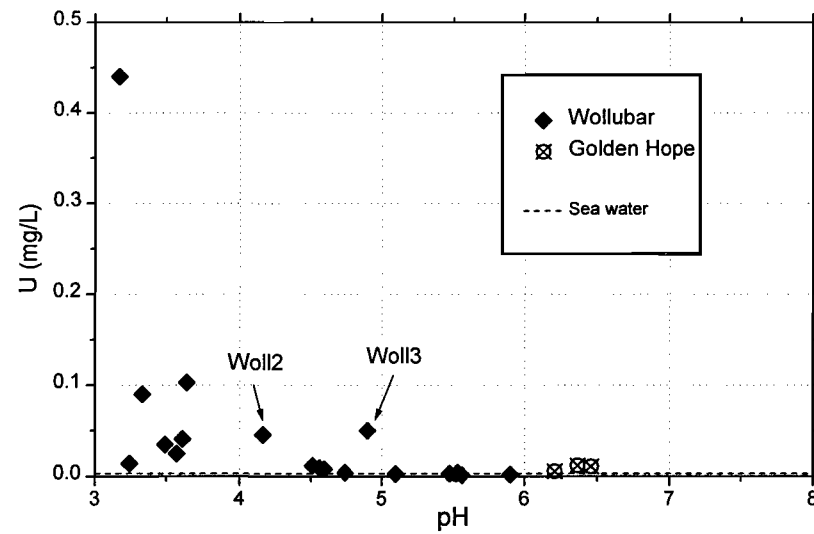


Figure A2.50: Uranium vs. pH for groundwaters from Wollubar palaeochannel and Golden Hope.

Appendix 3 - Speciation Analysis Output

Appendix 3.1 - Example of PHREEQE Output

```

3220.drilled
0000000000 0 0          .00000
SOLUTION 1
3220.drilled
18 10 2      6.62      4.09      25.0      1.18
 24 8.793D+04 21 1.289D+04 11 5.430D+02 19 8.260D+02 13 1.650D+05
 29 1.432D+04 10 4.622D+01 31 9.900D+00 8 2.710D-01 5 8.262D-03
 30 2.000D+00 22 1.810D+01 17 1.300D+00 14 1.100D-02 25 4.721D-02
 15 4.500D-02 34 9.700D-02 27 1.000D-02
SOLUTION NUMBER 1      3220.drilled

```

TOTAL MOLALITIES OF ELEMENTS

| ELEMENT | MOLALITY | LOG MOLALITY |
|---------|--------------|--------------|
| Al | 3.396991D-07 | -6.4689 |
| Ba | 2.189009D-06 | -5.6598 |
| TOT ALK | 8.404100D-04 | -3.0755 |
| Ca | 1.502960D-02 | -1.8231 |
| Cl | 5.163049D+00 | .7129 |
| Co | 2.070656D-07 | -6.6839 |
| Cu | 7.855965D-07 | -6.1048 |
| Fe | 2.582372D-05 | -4.5880 |
| K | 2.343454D-02 | -1.6301 |
| Mg | 5.880850D-01 | -.2306 |
| Mn | 3.654946D-04 | -3.4371 |
| Na | 4.242944D+00 | .6277 |
| Ni | 8.920665D-07 | -6.0496 |
| Pb | 5.354349D-08 | -7.2713 |
| SO4 | 1.653976D-01 | -.7815 |
| Si | 6.920568D-05 | -4.1599 |
| Sr | 1.253451D-04 | -3.9019 |
| Zn | 1.646149D-06 | -5.7835 |

-----DESCRIPTION OF SOLUTION-----

```

          PH =      6.62
          PE =      4.0906
    ACTIVITY H2O =      .8287
    IONIC STRENGTH =      5.7835
    TEMPERATURE =      25.0000
ELECTRICAL BALANCE = -2.1029D-02
          THOR =      9.9581D-01
    TOTAL ALKALINITY =      8.4041D-04
    ITERATIONS =      20
    TOTAL CARBON =      8.5325D-04

```

DISTRIBUTION OF SPECIES

| I | SPECIES | Z | MOLALITY | LOG MOLALITY | ACTIVITY | LOG ACTIVITY |
|-----|----------|------|----------|--------------|----------|--------------|
| 1 | H+ | 1.0 | 4.06D-06 | -5.39 | 2.40D-07 | -6.62 |
| 2 | E- | -1.0 | 8.12D-05 | -4.09 | 8.12D-05 | -4.09 |
| 3 | H2O | .0 | 8.29D-01 | -.08 | 8.29D-01 | -.08 |
| 5 | Al 3+ | 3.0 | 4.99D-15 | -14.30 | 2.68D-10 | -9.57 |
| 8 | Ba 2+ | 2.0 | 7.82D-08 | -7.11 | 9.90D-06 | -5.00 |
| 10 | CO3 2- | -2.0 | 2.53D-10 | -9.60 | 3.21D-08 | -7.49 |
| 11 | Ca 2+ | 2.0 | 1.36D-02 | -1.87 | 1.70D-02 | -1.77 |
| 13 | Cl- | -1.0 | 5.16D+00 | .71 | 2.72D+00 | .44 |
| 14 | Co 2+ | 2.0 | 9.48D-10 | -9.02 | 1.20D-07 | -6.92 |
| 15 | Cu 2+ | 2.0 | 1.87D-13 | -12.73 | 2.36D-11 | -10.63 |
| 17 | Fe 2+ | 2.0 | 2.58D-05 | -4.59 | 3.59D-06 | -5.44 |
| 19 | K+ | 1.0 | 2.34D-02 | -1.63 | 1.23D-02 | -1.91 |
| 21 | Mg 2+ | 2.0 | 4.79D-01 | -.32 | 1.09D+00 | .04 |
| 22 | Mn 2+ | 2.0 | 4.20D-07 | -6.38 | 5.31D-05 | -4.27 |
| 24 | Na+ | 1.0 | 4.23D+00 | .63 | 5.82D+00 | .76 |
| 25 | Ni 2+ | 2.0 | 3.53D-10 | -9.45 | 4.46D-08 | -7.35 |
| 27 | Pb 2+ | 2.0 | 9.25D-13 | -12.03 | 1.17D-10 | -9.93 |
| 29 | SO4 2- | -2.0 | 4.15D-02 | -1.38 | 1.61D-03 | -2.79 |
| 30 | H4SiO4 | .0 | 6.92D-05 | -4.16 | 2.62D-04 | -3.58 |
| 31 | Sr 2+ | 2.0 | 1.08D-05 | -4.97 | 1.37D-03 | -2.86 |
| 34 | Zn 2+ | 2.0 | 4.71D-10 | -9.33 | 5.95D-08 | -7.23 |
| 52 | Cu+ | 1.0 | 3.00D-13 | -12.52 | 1.01D-12 | -12.00 |
| 53 | Fe 3+ | 3.0 | 9.75D-14 | -13.01 | 4.23D-15 | -14.37 |
| 65 | OH- | -1.0 | 1.03D-08 | -7.99 | 3.45D-08 | -7.46 |
| 66 | H3SiO4 - | -1.0 | 4.82D-08 | -7.32 | 1.62D-07 | -6.79 |
| 78 | MgCO3 0 | .0 | 8.79D-06 | -5.06 | 3.33D-05 | -4.48 |
| 79 | MgHCO3 + | 1.0 | 6.19D-04 | -3.21 | 2.08D-03 | -2.68 |
| 80 | MgSO4 0 | .0 | 1.08D-01 | -.97 | 4.10D-01 | -.39 |
| 85 | CaHCO3 + | 1.0 | 8.64D-06 | -5.06 | 2.90D-05 | -4.54 |
| 86 | CaCO3 0 | .0 | 2.05D-07 | -6.69 | 7.76D-07 | -6.11 |
| 87 | CaSO4 0 | .0 | 1.44D-03 | -2.84 | 5.47D-03 | -2.26 |
| 93 | NaCO3 - | -1.0 | 1.04D-06 | -5.98 | 3.47D-06 | -5.46 |
| 94 | NaHCO3 0 | .0 | 1.42D-04 | -3.85 | 5.37D-04 | -3.27 |
| 95 | NaSO4 - | -1.0 | 1.40D-02 | -1.85 | 4.69D-02 | -1.33 |
| 99 | KSO4 - | -1.0 | 4.16D-05 | -4.38 | 1.39D-04 | -3.86 |
| 101 | AlOH 2+ | 2.0 | 7.32D-11 | -10.14 | 9.26D-09 | -8.03 |
| 102 | Al(OH)2+ | 1.0 | 7.57D-08 | -7.12 | 2.54D-07 | -6.60 |
| 103 | Al(OH)3 | .0 | 3.67D-08 | -7.44 | 1.39D-07 | -6.86 |
| 104 | Al(OH)4- | -1.0 | 2.27D-07 | -6.64 | 7.61D-07 | -6.12 |
| 109 | AlSO4 + | 1.0 | 1.35D-10 | -9.87 | 4.51D-10 | -9.35 |
| 113 | FeOH 2+ | 2.0 | 7.45D-13 | -12.13 | 9.43D-11 | -10.03 |
| 114 | FeOH2 + | 1.0 | 3.22D-08 | -7.49 | 1.08D-07 | -6.97 |
| 115 | FeOH3 0 | .0 | 1.27D-08 | -7.90 | 4.80D-08 | -7.32 |
| 116 | FeOH4 - | -1.0 | 4.51D-11 | -10.35 | 1.51D-10 | -9.82 |
| 120 | FeSO4 + | 1.0 | 2.22D-14 | -13.65 | 7.45D-14 | -13.13 |
| 121 | FeCl 2+ | 2.0 | 2.75D-15 | -14.56 | 3.48D-13 | -12.46 |
| 122 | FeCl2 + | 1.0 | 1.26D-12 | -11.90 | 4.23D-12 | -11.37 |
| 131 | Fe(SO4)2 | -1.0 | 7.82D-16 | -15.11 | 2.62D-15 | -14.58 |
| 135 | SrHCO3 + | 1.0 | 1.01D-06 | -5.99 | 3.40D-06 | -5.47 |
| 136 | SrCO3 | .0 | 7.49D-09 | -8.13 | 2.84D-08 | -7.55 |
| 137 | SrSO4 | .0 | 1.13D-04 | -3.95 | 4.30D-04 | -3.37 |
| 139 | BaHCO3 + | 1.0 | 4.64D-09 | -8.33 | 1.56D-08 | -7.81 |
| 140 | BaCO3 | .0 | 4.30D-11 | -10.37 | 1.63D-10 | -9.79 |
| 141 | BaSO4 | .0 | 2.11D-06 | -5.68 | 7.98D-06 | -5.10 |
| 142 | MnCl + | 1.0 | 1.76D-04 | -3.76 | 5.89D-04 | -3.23 |
| 143 | MnCl2 0 | .0 | 1.85D-04 | -3.73 | 7.01D-04 | -3.15 |
| 146 | Mn(OH)3 | -1.0 | 1.04D-20 | -19.99 | 3.47D-20 | -19.46 |
| 148 | MnSO4 0 | .0 | 4.01D-06 | -5.40 | 1.52D-05 | -4.82 |

| | | | | | | |
|-----|-----------------------------------|------|----------|--------|----------|--------|
| 149 | MnHCO ₃ + | 1.0 | 2.32D-07 | -6.64 | 7.76D-07 | -6.11 |
| 150 | MnCO ₃ 0 | .0 | 3.57D-08 | -7.45 | 1.35D-07 | -6.87 |
| 151 | CuCl ₂ - | -1.0 | 7.05D-07 | -6.15 | 2.36D-06 | -5.63 |
| 152 | CuCl ₃ 2- | -2.0 | 8.07D-08 | -7.09 | 1.02D-05 | -4.99 |
| 153 | CuCO ₃ 0 | .0 | 1.07D-12 | -11.97 | 4.07D-12 | -11.39 |
| 154 | Cu(CO ₃) ₂ | -2.0 | 3.04D-18 | -17.52 | 3.85D-16 | -15.41 |
| 155 | CuCl + | 1.0 | 5.17D-11 | -10.29 | 1.73D-10 | -9.76 |
| 156 | CuCl ₂ 0 | .0 | 6.70D-11 | -10.17 | 2.54D-10 | -9.60 |
| 160 | CuOH + | 1.0 | 7.70D-13 | -12.11 | 2.58D-12 | -11.59 |
| 161 | Cu(OH) ₂ | .0 | 4.70D-15 | -14.33 | 1.78D-14 | -13.75 |
| 165 | CuSO ₄ 0 | .0 | 2.05D-12 | -11.69 | 7.77D-12 | -11.11 |
| 167 | CuHCO ₃ + | 1.0 | 6.83D-14 | -13.17 | 2.29D-13 | -12.64 |
| 168 | ZnCl + | 1.0 | 1.30D-07 | -6.89 | 4.37D-07 | -6.36 |
| 169 | ZnCl ₂ 0 | .0 | 3.29D-07 | -6.48 | 1.25D-06 | -5.90 |
| 170 | ZnCl ₃ - | -1.0 | 1.13D-06 | -5.95 | 3.81D-06 | -5.42 |
| 171 | ZnCl ₄ 2- | -2.0 | 4.10D-08 | -7.39 | 5.18D-06 | -5.29 |
| 173 | ZnOH + | 1.0 | 6.42D-11 | -10.19 | 2.15D-10 | -9.67 |
| 174 | Zn(OH) ₂ | .0 | 2.37D-12 | -11.63 | 8.97D-12 | -11.05 |
| 177 | ZnOHCl 0 | .0 | 4.90D-09 | -8.31 | 1.86D-08 | -7.73 |
| 180 | ZnSO ₄ 0 | .0 | 5.93D-09 | -8.23 | 2.24D-08 | -7.65 |
| 181 | Zn(SO ₄) ₂ | -2.0 | 2.32D-12 | -11.63 | 2.93D-10 | -9.53 |
| 186 | ZnHCO ₃ + | 1.0 | 1.46D-11 | -10.83 | 4.91D-11 | -10.31 |
| 187 | ZnCO ₃ 0 | .0 | 7.99D-11 | -10.10 | 3.03D-10 | -9.52 |
| 188 | Zn(CO ₃) ₂ | -2.0 | 2.06D-15 | -14.69 | 2.61D-13 | -12.58 |
| 214 | PbCl + | 1.0 | 3.78D-09 | -8.42 | 1.27D-08 | -7.90 |
| 215 | PbCl ₂ 0 | .0 | 1.45D-08 | -7.84 | 5.48D-08 | -7.26 |
| 216 | PbCl ₃ - | -1.0 | 3.53D-08 | -7.45 | 1.18D-07 | -6.93 |
| 217 | PbCO ₃ 0 | .0 | 2.49D-13 | -12.60 | 9.42D-13 | -12.03 |
| 218 | PbHCO ₃ + | 1.0 | 4.25D-12 | -11.37 | 1.43D-11 | -10.85 |
| 219 | Pb(CO ₃) ₂ | -2.0 | 6.88D-19 | -18.16 | 8.71D-17 | -16.06 |
| 223 | PbOH + | 1.0 | 2.35D-12 | -11.63 | 7.88D-12 | -11.10 |
| 224 | Pb(OH) ₂ | .0 | 2.80D-15 | -14.55 | 1.06D-14 | -13.97 |
| 228 | PbSO ₄ 0 | .0 | 2.79D-11 | -10.55 | 1.06D-10 | -9.98 |
| 243 | NiOH + | 1.0 | 6.34D-12 | -11.20 | 2.13D-11 | -10.67 |
| 244 | Ni(OH) ₂ | .0 | 1.41D-14 | -13.85 | 5.33D-14 | -13.27 |
| 245 | NiHCO ₃ + | 1.0 | 8.51D-11 | -10.07 | 2.85D-10 | -9.54 |
| 246 | NiCO ₃ 0 | .0 | 1.40D-12 | -11.85 | 5.31D-12 | -11.27 |
| 248 | NiCl + | 1.0 | 9.08D-08 | -7.04 | 3.05D-07 | -6.52 |
| 249 | NiCl ₂ 0 | .0 | 7.97D-07 | -6.10 | 3.02D-06 | -5.52 |
| 250 | NiSO ₄ 0 | .0 | 3.69D-09 | -8.43 | 1.40D-08 | -7.85 |
| 278 | HCO ₃ - | -1.0 | 4.90D-05 | -4.31 | 1.64D-04 | -3.78 |
| 279 | H ₂ CO ₃ 0 | .0 | 2.32D-05 | -4.63 | 8.80D-05 | -4.06 |
| 425 | CoOH + | 1.0 | 2.46D-11 | -10.61 | 8.26D-11 | -10.08 |
| 426 | Co(OH) ₂ | .0 | 9.49D-15 | -14.02 | 3.59D-14 | -13.44 |
| 427 | CoHCO ₃ + | 1.0 | 1.44D-10 | -9.84 | 4.84D-10 | -9.32 |
| 428 | CoCO ₃ 0 | .0 | 1.50D-12 | -11.82 | 5.68D-12 | -11.25 |
| 429 | CoSO ₄ | .0 | 1.17D-08 | -7.93 | 4.42D-08 | -7.35 |
| 430 | CoCl + | 1.0 | 1.94D-07 | -6.71 | 6.52D-07 | -6.19 |

| PHASE | LOG IAP | LOG KT | LOG IAP/KT |
|----------|-----------|----------|------------|
| Calcite | -9.2628 | -8.4749 | -.79 |
| Gypsum | -4.7255 | -4.5800 | -.15 |
| Dolo-ord | -16.7204 | -17.0900 | .37 |
| Magnesit | -7.4576 | -8.0300 | .57 |
| Epsomite | -3.3282 | -2.1400 | -1.19 |
| Strontia | -10.3572 | -9.2700 | -1.09 |
| Celestit | -5.6567 | -6.6300 | .97 |
| Witherit | -12.4986 | -8.5600 | -3.94 |
| Barite | -7.7982 | -9.9700 | 2.17 |
| Halite | 1.2000 | 1.5800 | -.38 |
| Quartz | -3.4186 | -3.9800 | .56 |
| SiO2(a) | -3.4186 | -2.7148 | -.70 |
| Gibbs(c) | 10.0432 | 8.1100 | 1.93 |
| AlOH3(a) | 10.0432 | 10.3800 | -.34 |
| Basal(c) | 24.3024 | 22.3000 | 2.00 |
| K-Alunit | 3.0184 | -1.4000 | 4.42 |
| Jurbani | -5.8273 | -3.8000 | -2.03 |
| Kaolinit | 13.3307 | 7.4400 | 5.89 |
| FeS PPT | -93.5967 | -37.5800 | -56.02 |
| Siderite | -12.9387 | -10.5500 | -2.39 |
| Fe3(OH)8 | 44.1550 | 46.2900 | -2.14 |
| Ferrihñl | 18.2613 | 17.0000 | 1.26 |
| Goethite | 18.3429 | 12.0200 | 6.32 |
| K-Jarosi | 27.6728 | 24.3000 | 3.37 |
| Rhod-cry | -11.7689 | -11.1300 | -.64 |
| Pyrocroi | 8.8021 | 15.2000 | -6.40 |
| Hausmani | 47.9906 | 61.0300 | -13.04 |
| Manganit | 19.5127 | 25.3400 | -5.83 |
| Pyrolusi | 30.2233 | 41.3800 | -11.16 |
| Tenorite | 2.5322 | 7.6200 | -5.09 |
| Malachit | -15.6697 | -5.1800 | -10.49 |
| Atacamit | -1.2019 | 7.3400 | -8.54 |
| Smithson | -14.7193 | -10.0000 | -4.72 |
| Zincite | 5.9333 | 11.1400 | -5.21 |
| Zn3O(SO4 | -14.1043 | 19.0200 | -33.12 |
| Cerrusit | -17.4259 | -13.1300 | -4.30 |
| PbCl.5(O | .0935 | 4.0000 | -3.91 |
| Laurioni | -2.9581 | .6200 | -3.58 |
| Anglesit | -12.7254 | -7.7900 | -4.94 |
| NiCO3 | -14.8446 | -6.8400 | -8.00 |
| Ni(OH)2 | 5.7263 | 10.8000 | -5.07 |
| Co(OH)2 | 6.1556 | 13.1000 | -6.94 |
| CoCO3 | -14.4154 | -9.9800 | -4.44 |
| CO2(gas) | -20.6526 | -18.1500 | -2.50 |
| O2(gas) | 42.6792 | 83.1200 | -40.44 |
| CH4(GAS) | -106.1742 | -41.0800 | -65.09 |

Appendix 3.2 - SI Plots

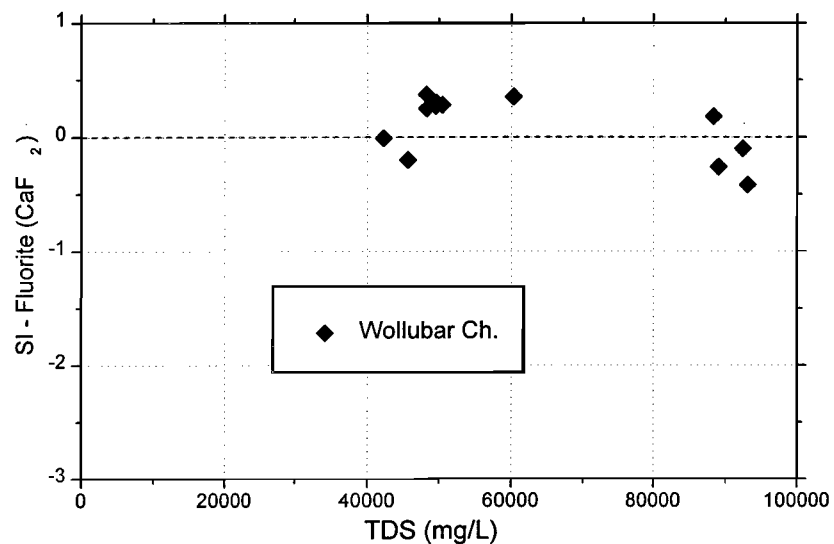


Figure A3.1: SI for fluorite vs. TDS for Wollubar palaeo-channel and Golden Hope groundwaters.

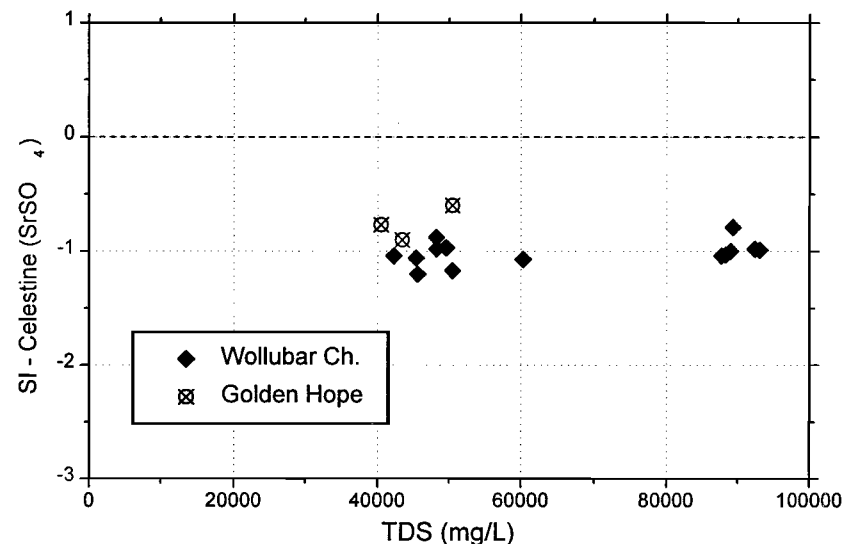


Figure A3.3: SI for celestine vs. TDS for Wollubar palaeo-channel and Golden Hope groundwaters.

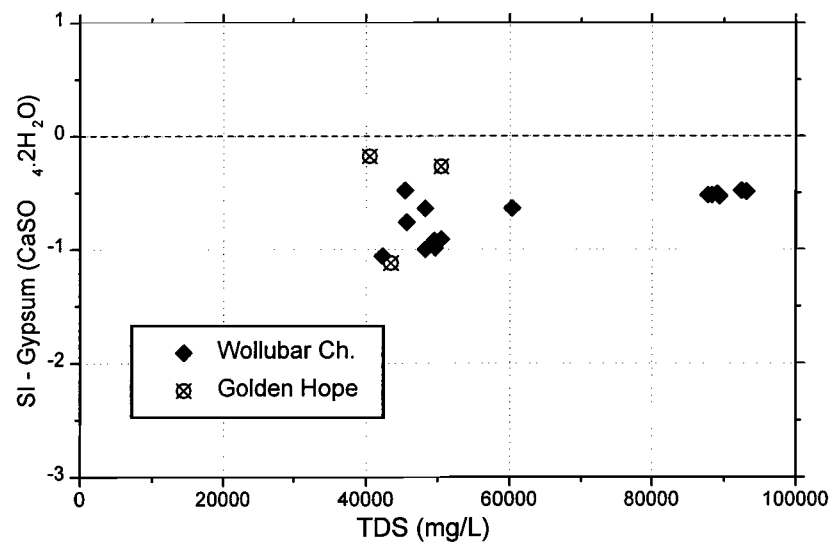


Figure A3.2: SI for gypsum vs. TDS for Wollubar palaeo-channel and Golden Hope groundwaters.

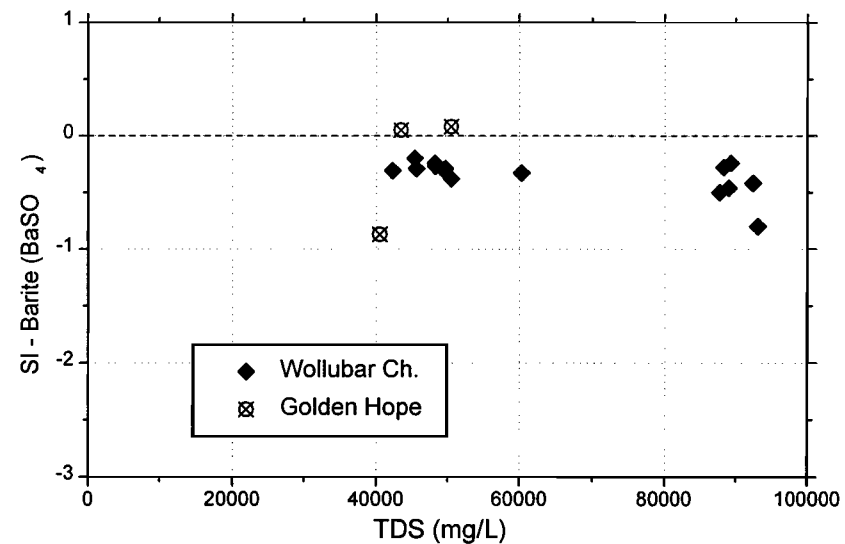


Figure A3.4: SI for barite vs. TDS for Wollubar palaeo-channel and Golden Hope groundwaters.

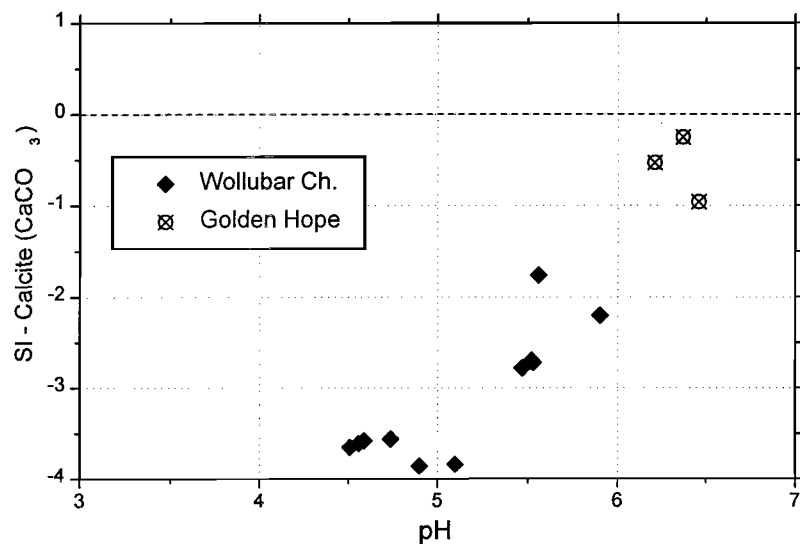


Figure A3.5: SI for calcite vs. pH for Wollubar palaeo-channel and Golden Hope groundwaters.

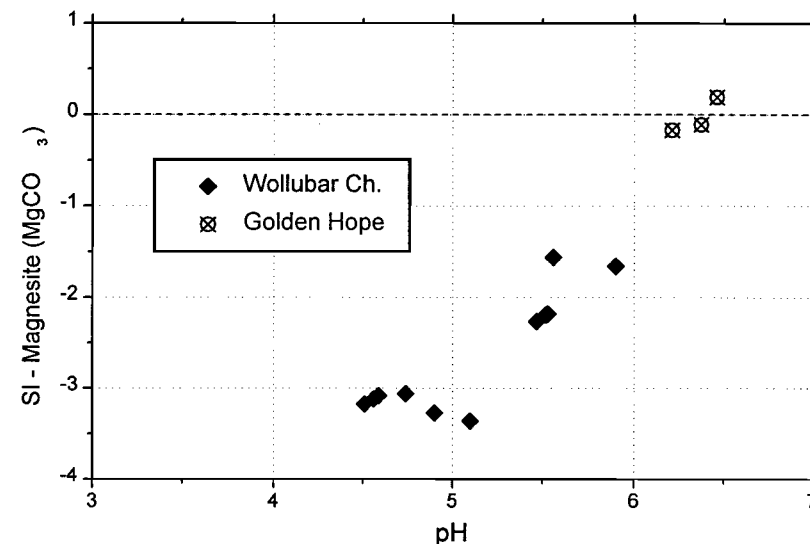


Figure A3.7: SI for magnesite vs. pH for Wollubar palaeo-channel and Golden Hope groundwaters.

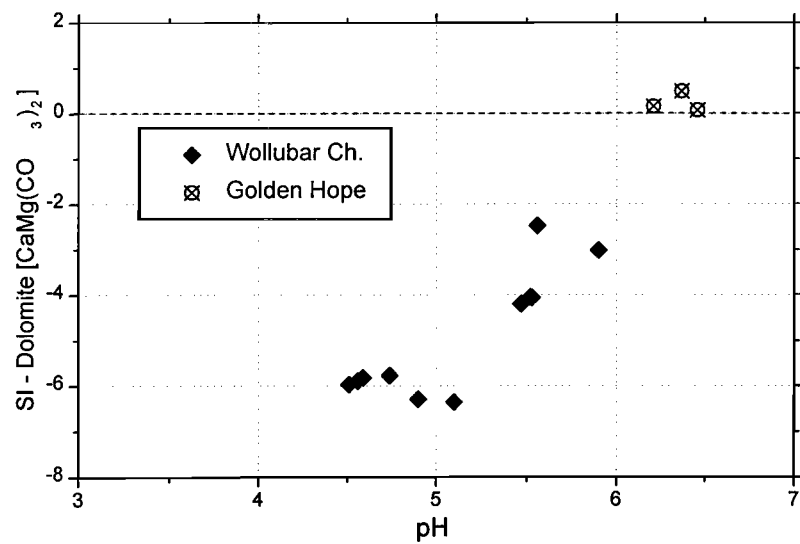


Figure A3.6: SI for dolomite vs. pH for Wollubar palaeo-channel and Golden Hope groundwaters.

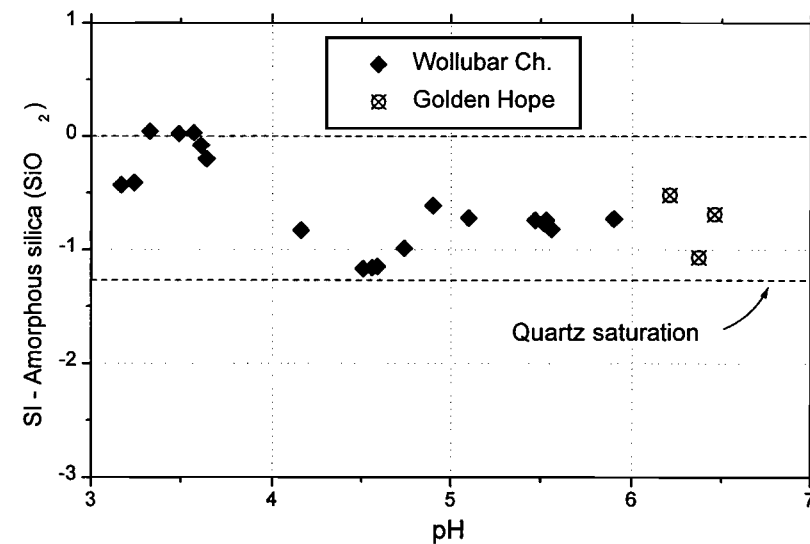


Figure A3.8: SI for SiO₂ vs. pH for Wollubar palaeo-channel and Golden Hope groundwaters.

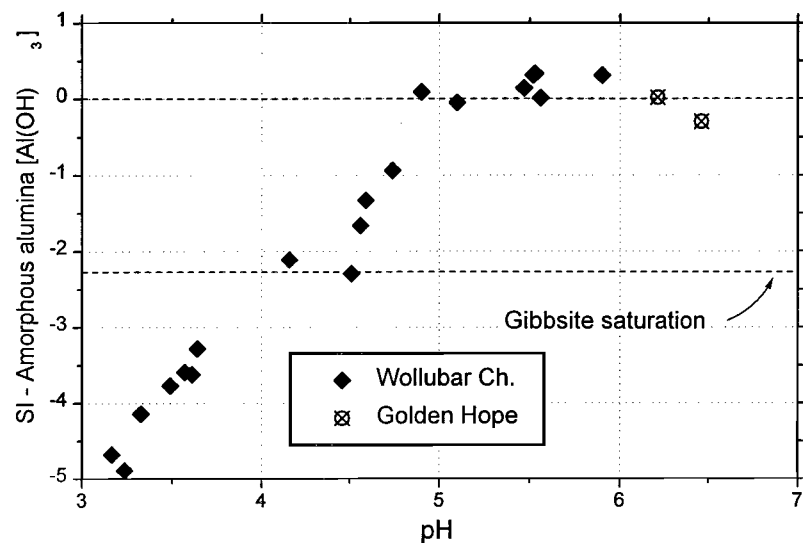


Figure A3.9: SI for alumina vs. pH for Wollubar palaeo-channel and Golden Hope groundwaters.

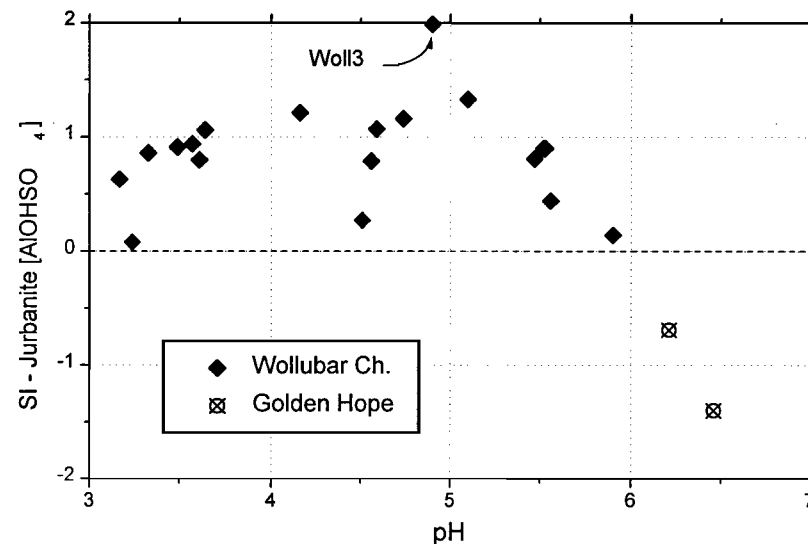


Figure A3.11: SI for jurbanite vs. pH for Wollubar palaeo-channel and Golden Hope groundwaters.

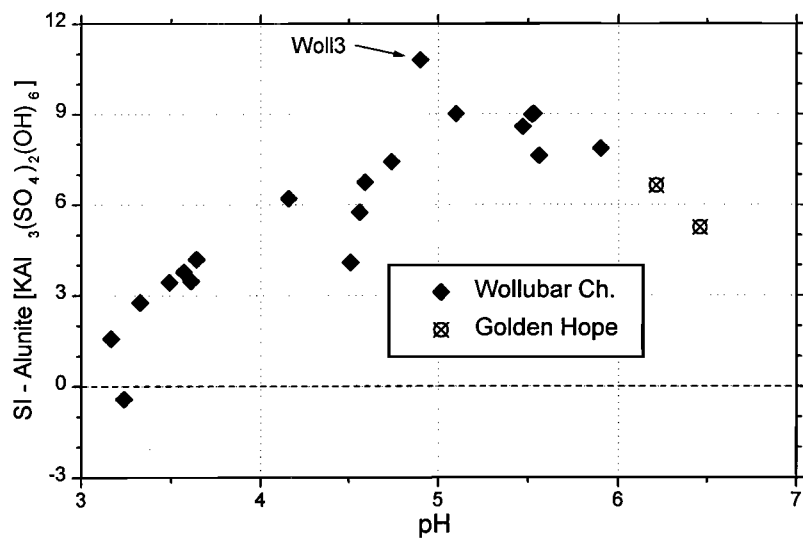


Figure A3.10: SI for alunite vs. pH for Wollubar palaeo-channel and Golden Hope groundwaters.

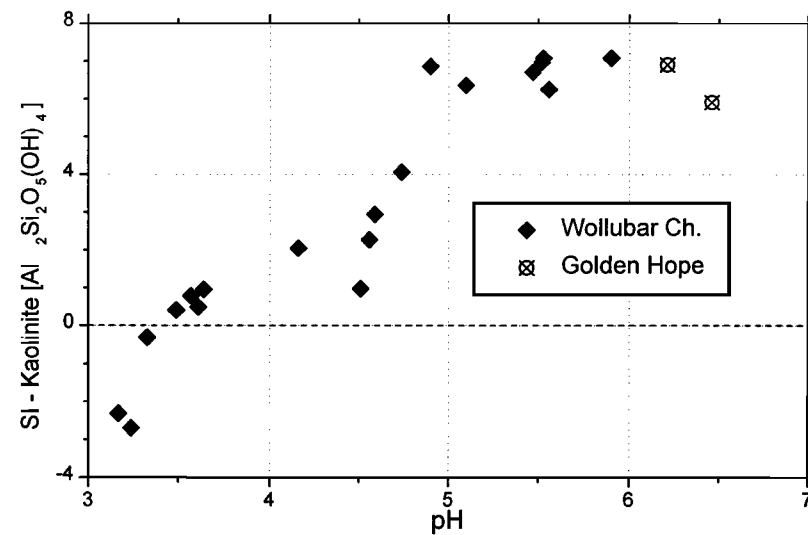


Figure A3.12: SI for kaolinite vs. pH for Wollubar palaeo-channel and Golden Hope groundwaters.

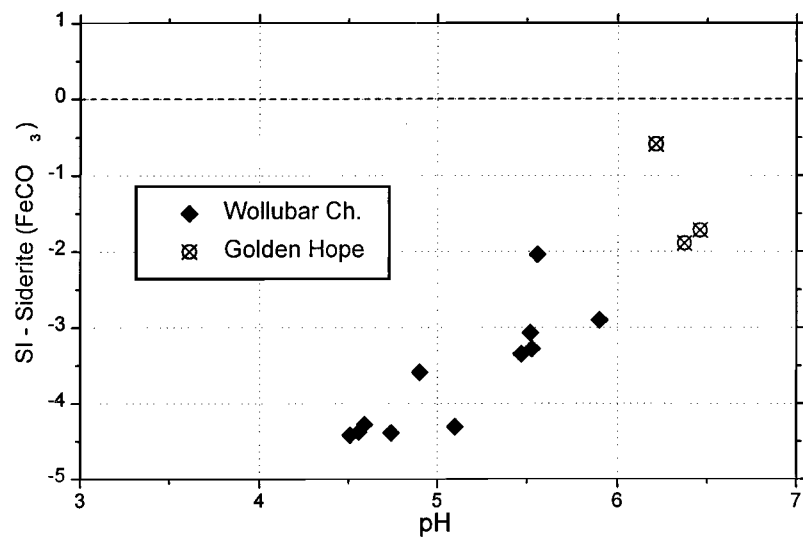


Figure A3.13: SI for siderite vs. pH for Wollubar palaeo-channel and Golden Hope groundwaters.

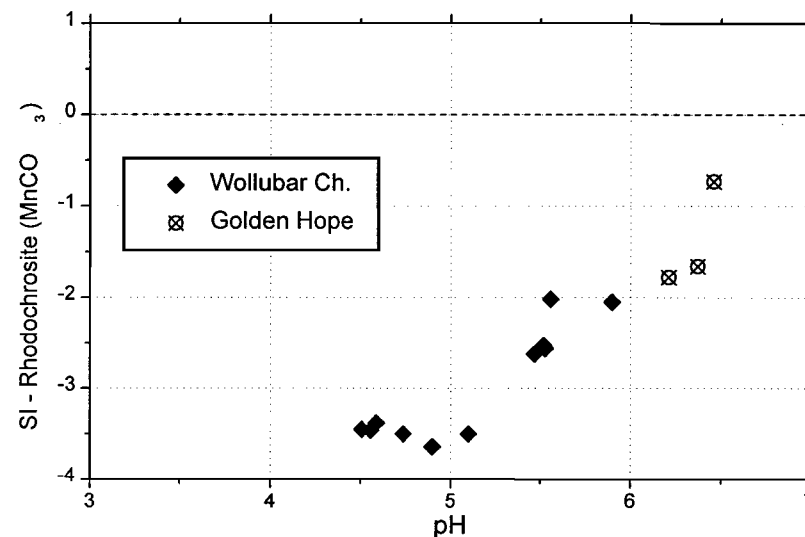


Figure A3.15: SI for rhodochrosite vs. pH for Wollubar palaeo-channel and Golden Hope groundwaters.

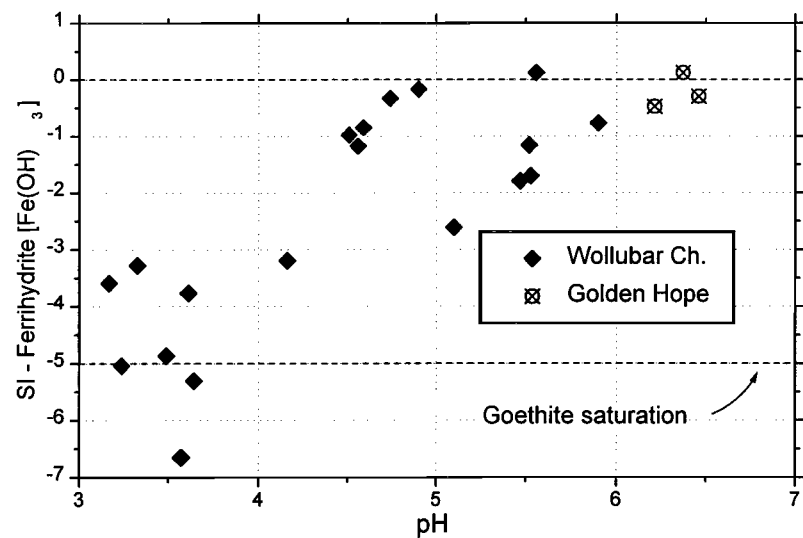


Figure A3.14: SI for ferrihydrate vs. pH for Wollubar palaeo-channel and Golden Hope groundwaters.

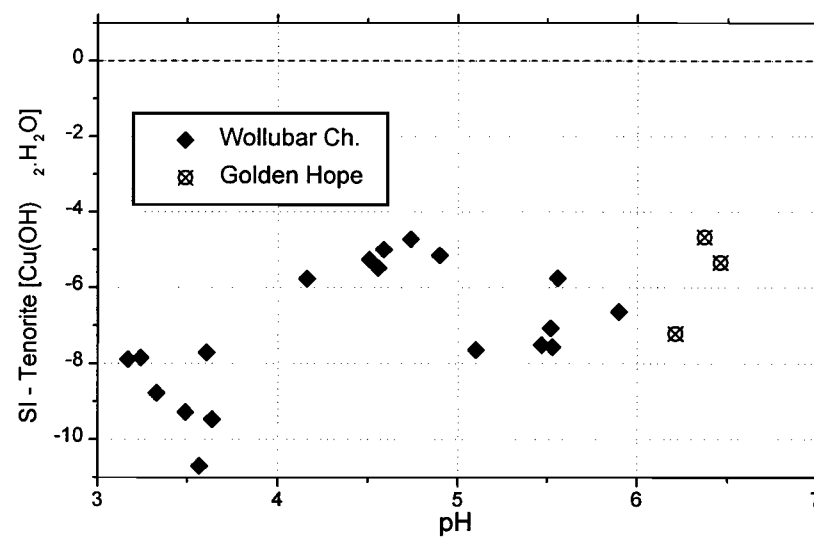


Figure A3.16: SI for tenorite vs. pH for Wollubar palaeo-channel and Golden Hope groundwaters.

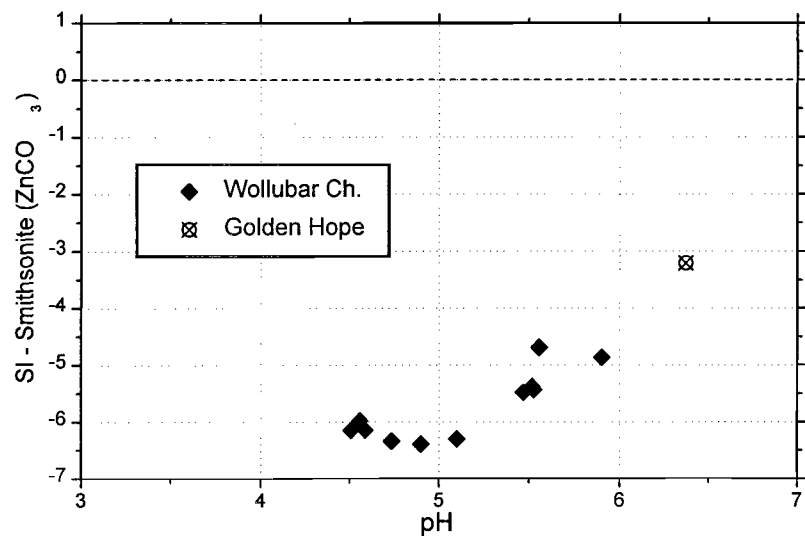


Figure A3.17: SI for smithsonite vs. pH for Wollubar palaeo-channel and Golden Hope groundwaters.

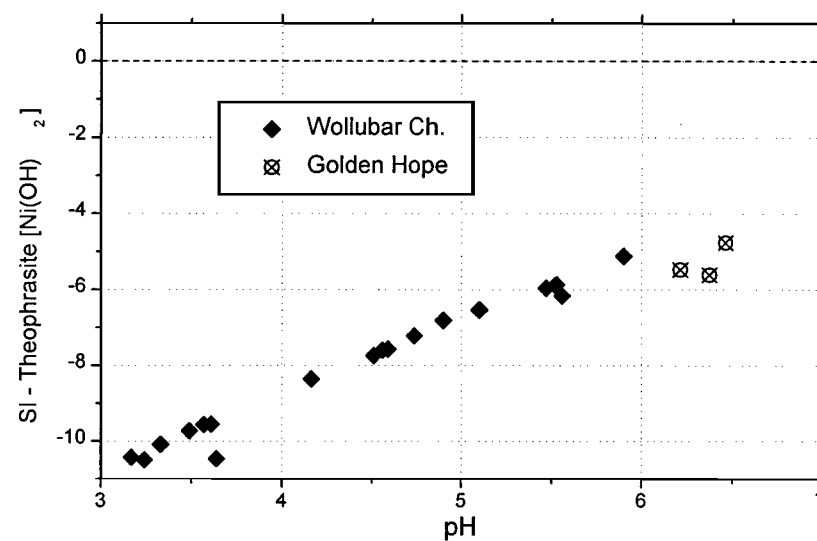


Figure A3.19: SI for Theophrasite vs. pH for Wollubar palaeo-channel and Golden Hope groundwaters.

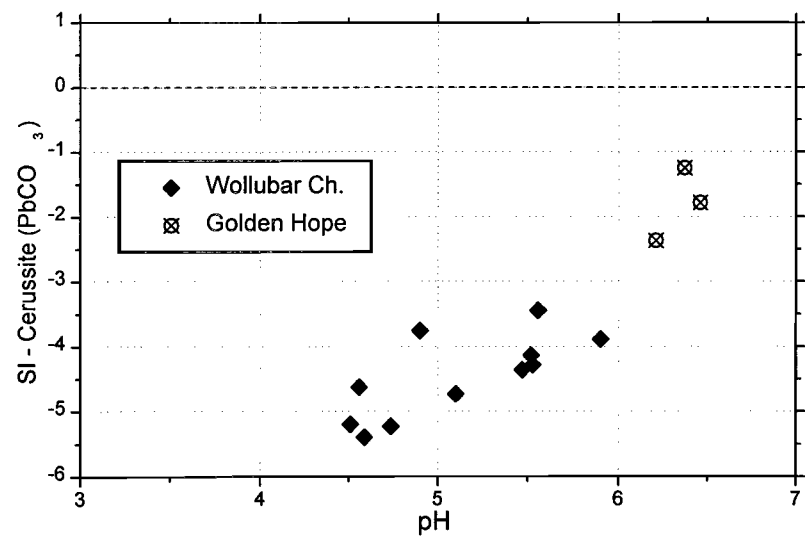


Figure A3.18: SI for cerussite vs. pH for Wollubar palaeo-channel and Golden Hope groundwaters.

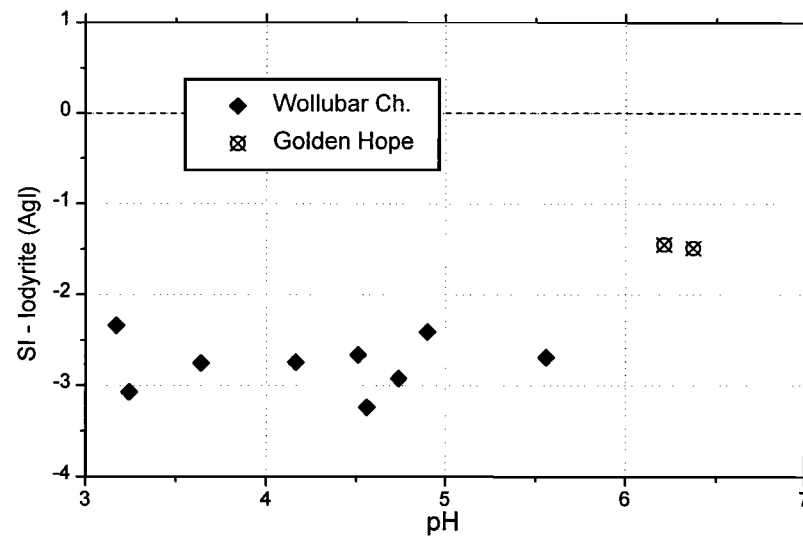


Figure A3.20: SI for iodyrite vs. pH for Wollubar palaeo-channel and Golden Hope groundwaters.

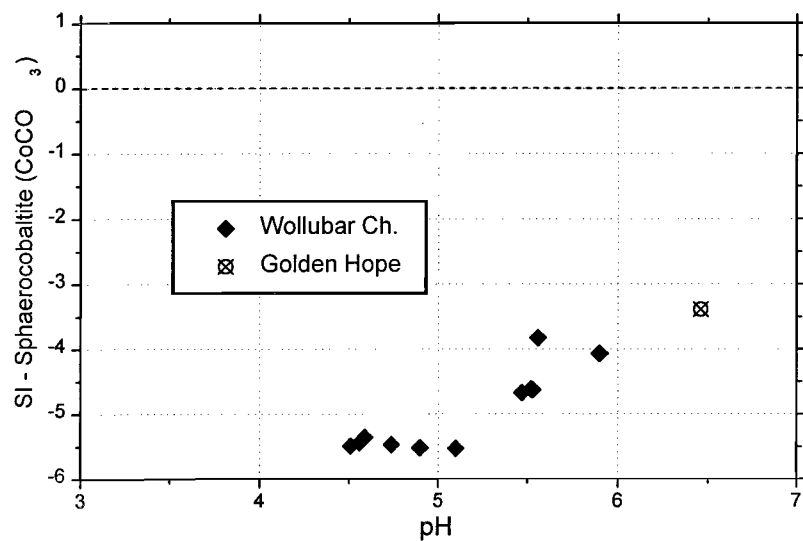


Figure A3.21: SI for sphaerocobaltite vs. pH for Wollubar palaeochannel and Golden Hope groundwaters.

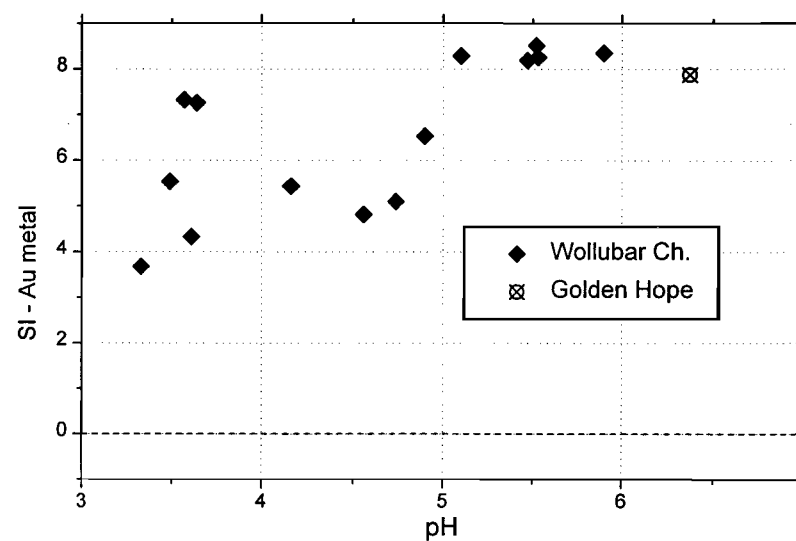


Figure A3.23: SI for Au metal vs. pH for Wollubar palaeochannel and Golden Hope groundwaters.

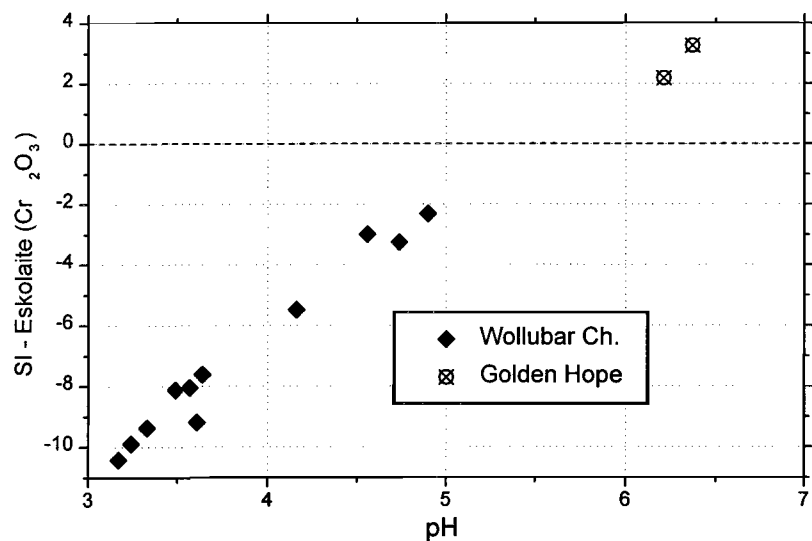


Figure A3.22: SI for eskolaite vs. pH for Wollubar palaeochannel and Golden Hope groundwaters.

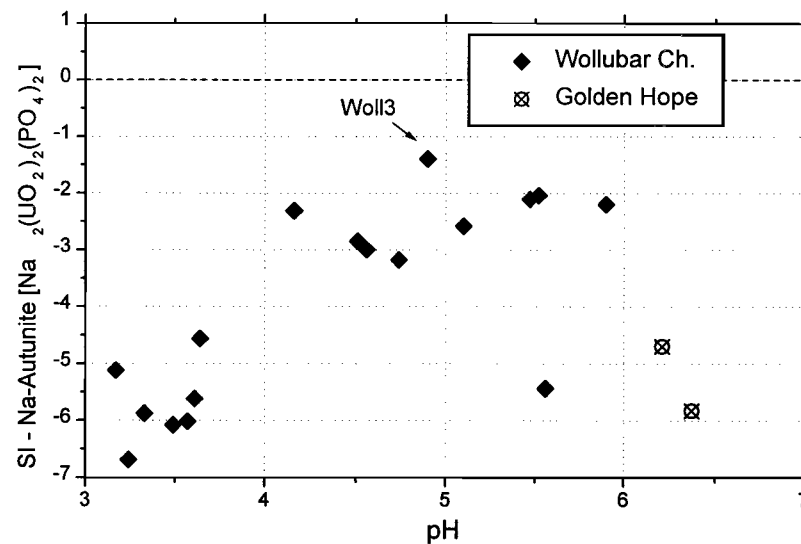


Figure A3.24: SI for Na-Autunite vs. pH for Wollubar palaeochannel and Golden Hope groundwaters.

**Appendix 4 - Chondrite Normalized REE Data for
groundwater samples**

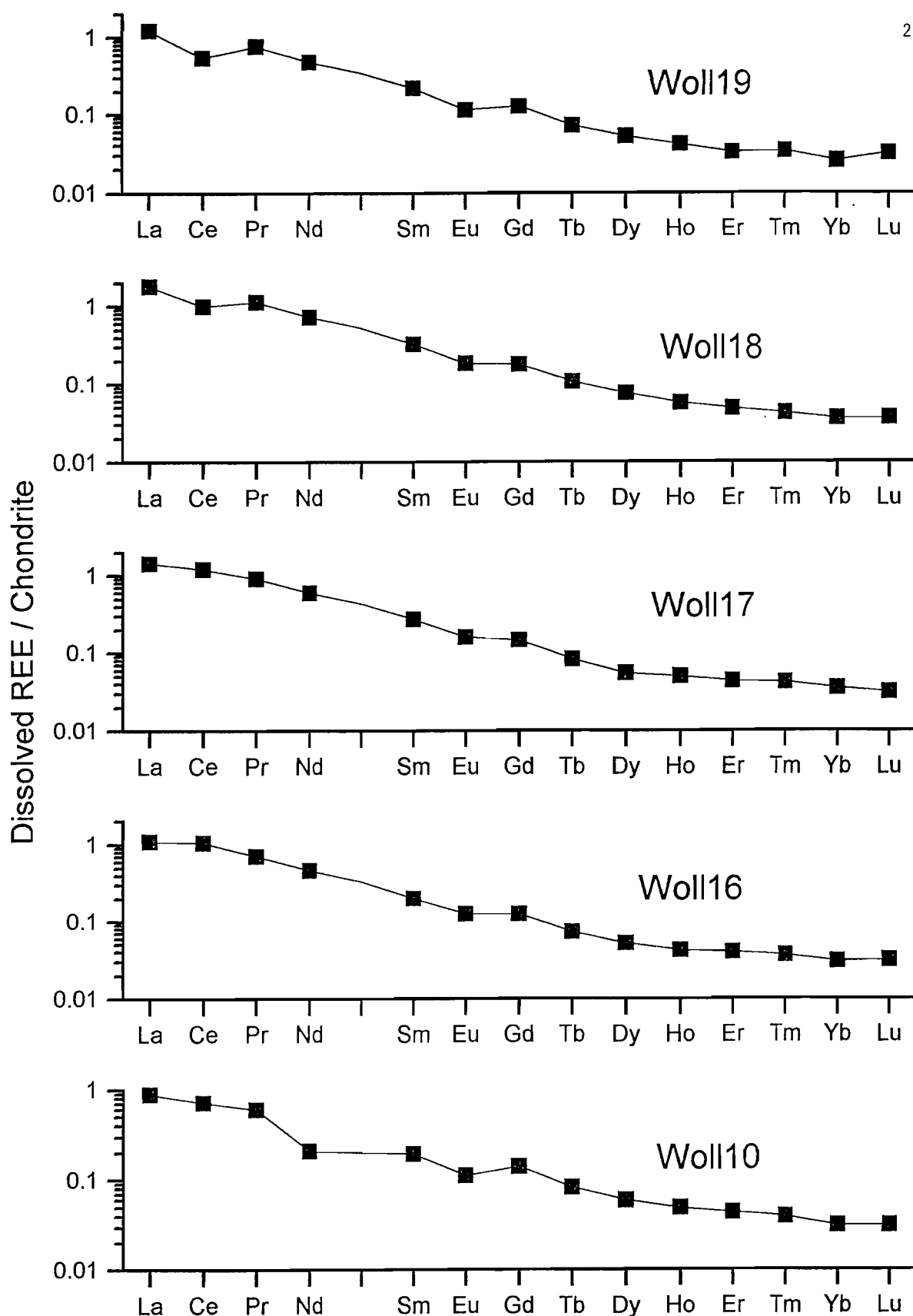


Figure A4.1: Chondrite normalized data for groundwaters from Woll19, Woll18, Woll17, Woll16 and Woll10 (see Figure 5 for bore hole positions).

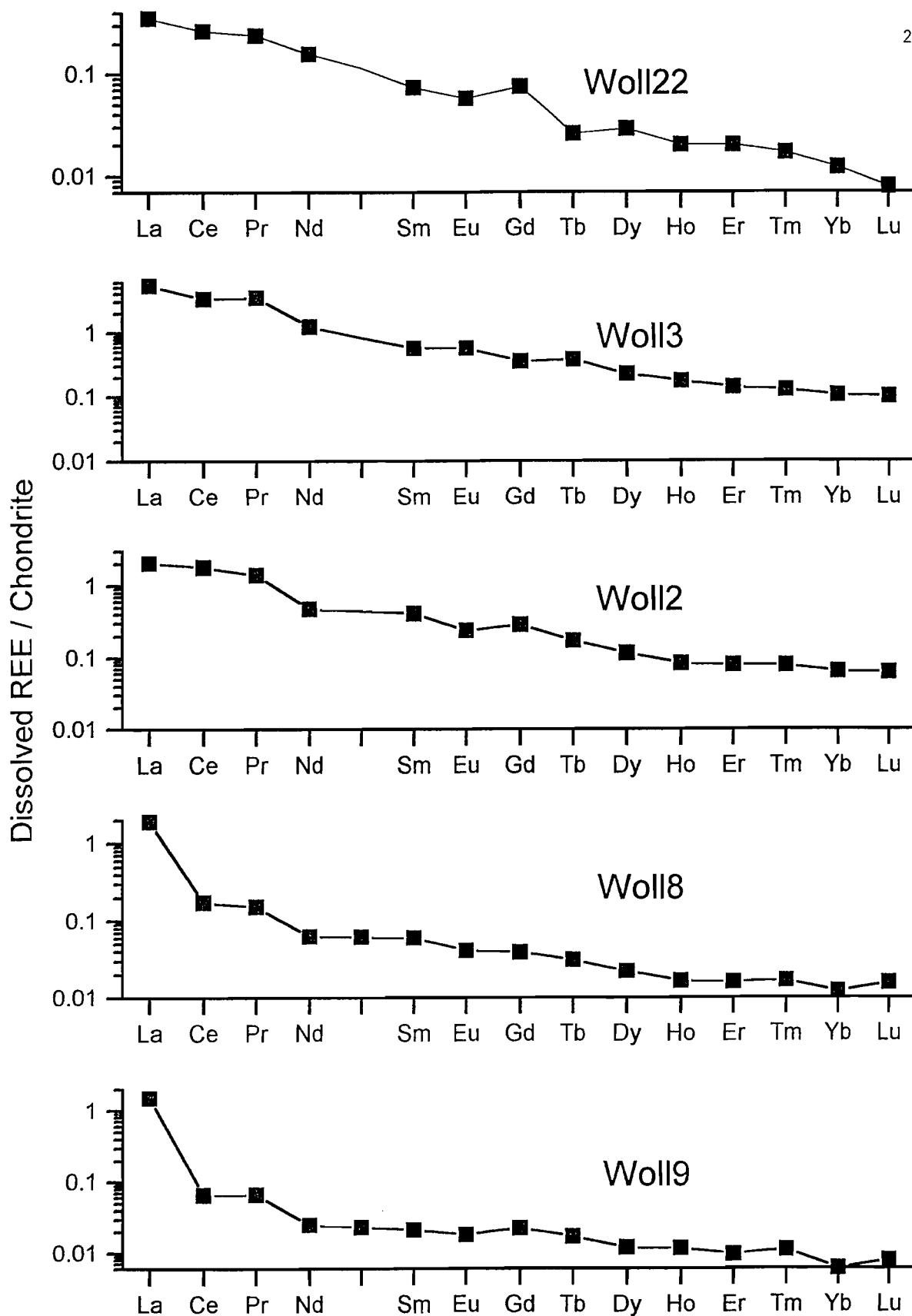


Figure A4.2: Chondrite normalized data for groundwaters from Woll22, Woll3, Woll2, Woll8 and Woll9 (see Figure 5 for bore hole positions).

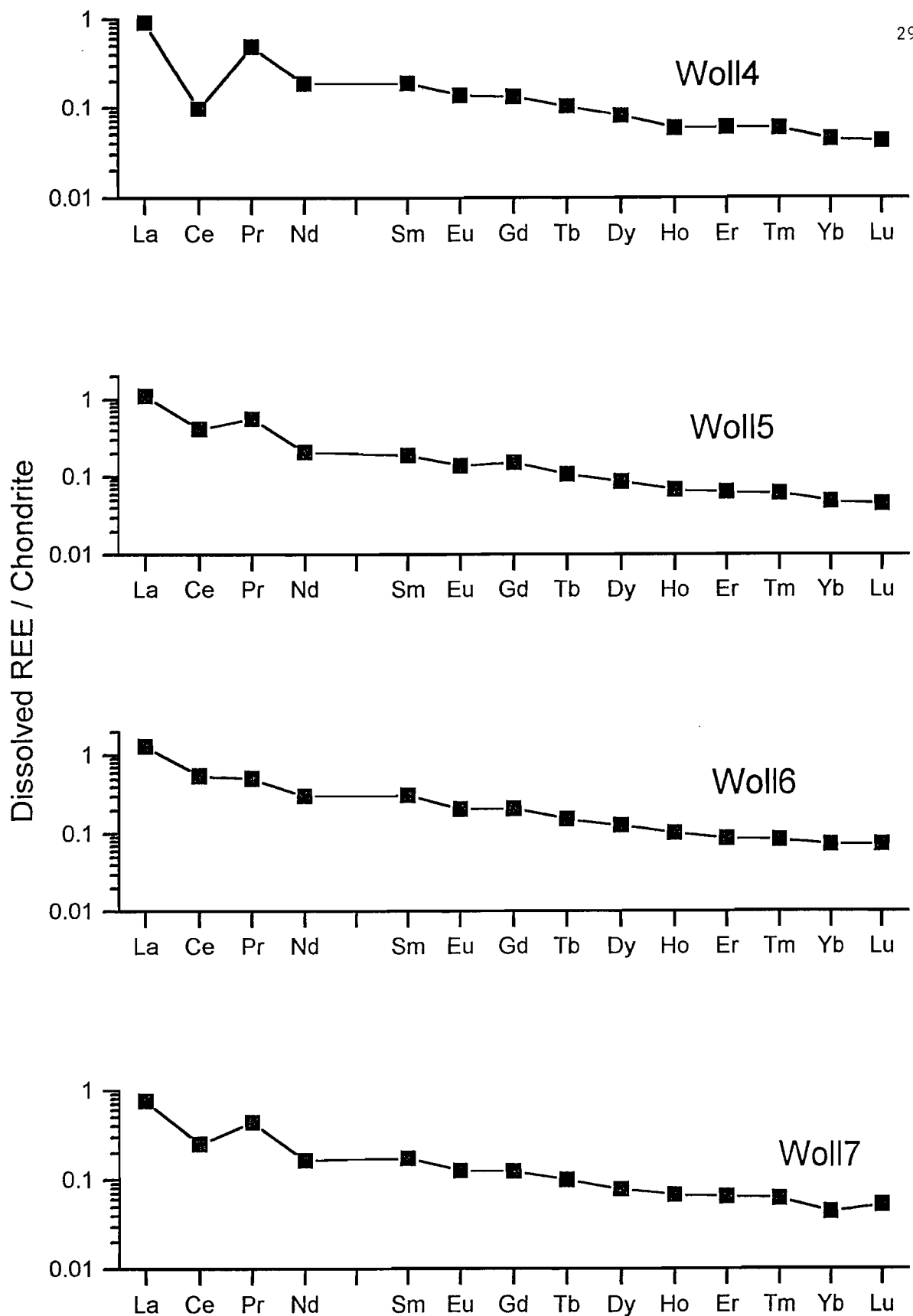


Figure A4.3: Chondrite normalized data for groundwaters from Woll4, Woll5, Woll6 and Woll7 (see Figure 5 for bore hole positions).

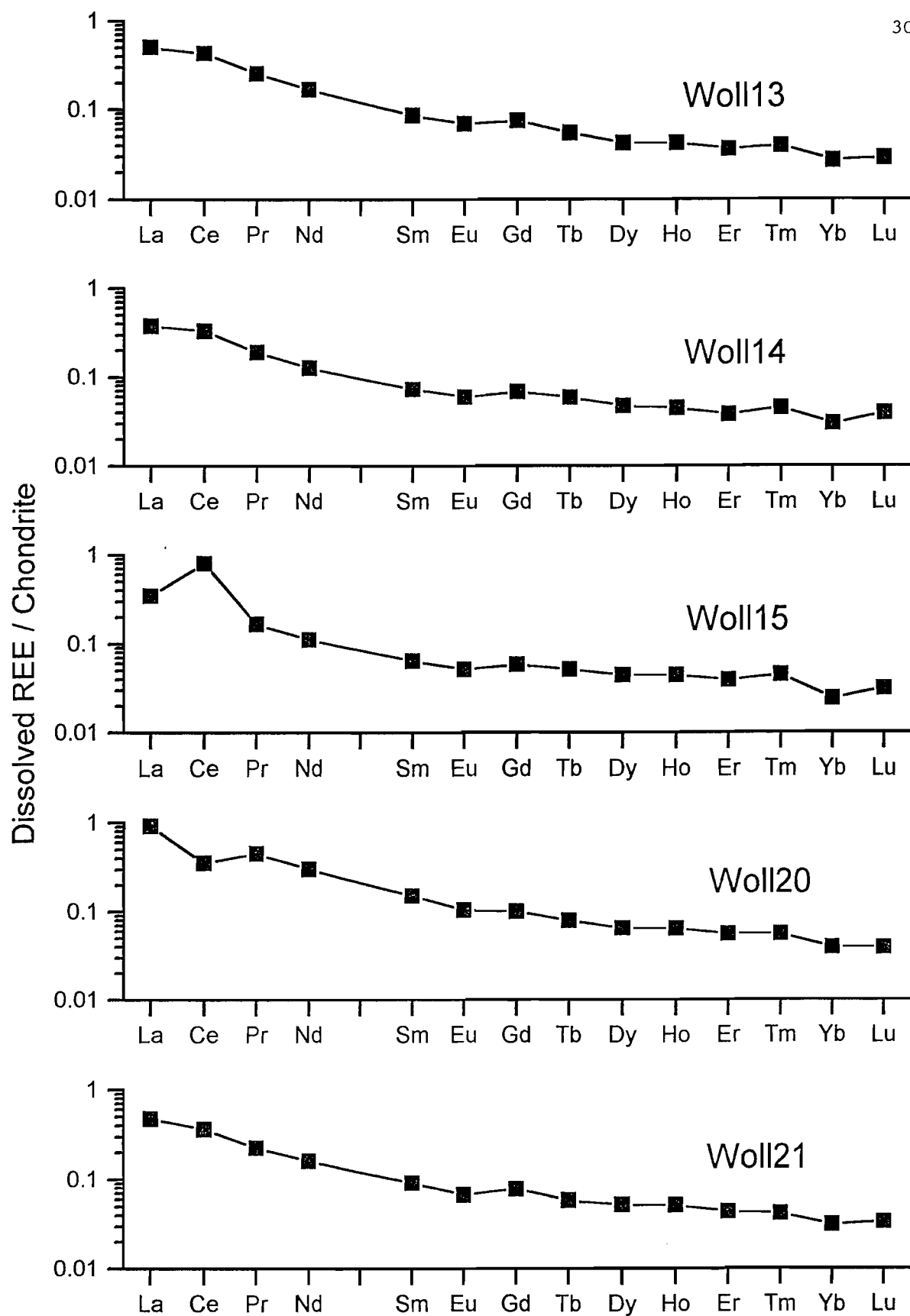


Figure A4.4: Chondrite normalized data for groundwaters from Woll13, Woll14, Woll15, Woll20 and Woll21 (see Figure 5 for bore hole positions).

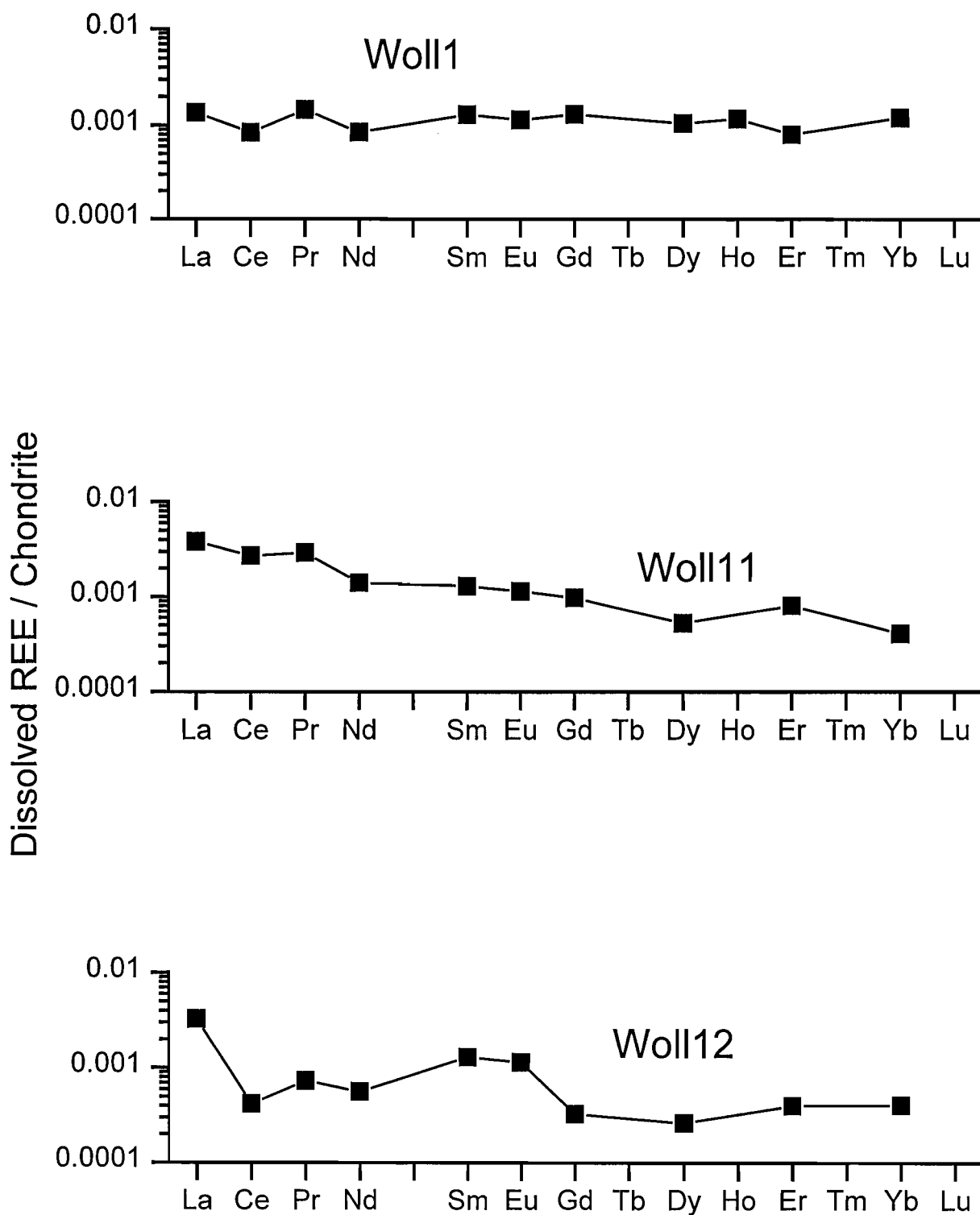


Figure A4.5: Chondrite normalized data for groundwaters from Woll1, Woll11 and Woll12 (see Figure 5 for bore hole positions).

Appendix 5 - Element/Ion Distribution Maps

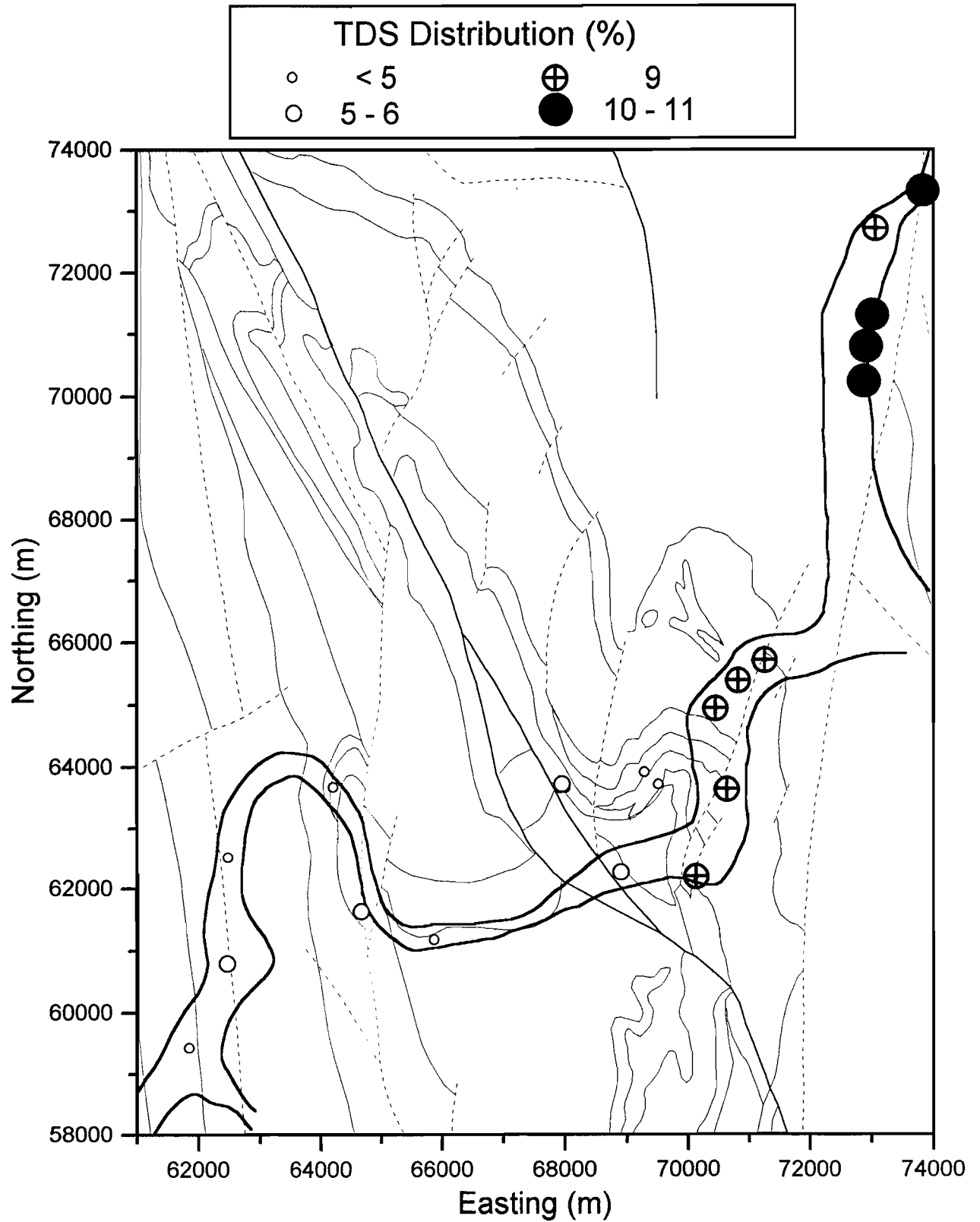


Figure A5.1: TDS distribution in groundwater at Wollubar.

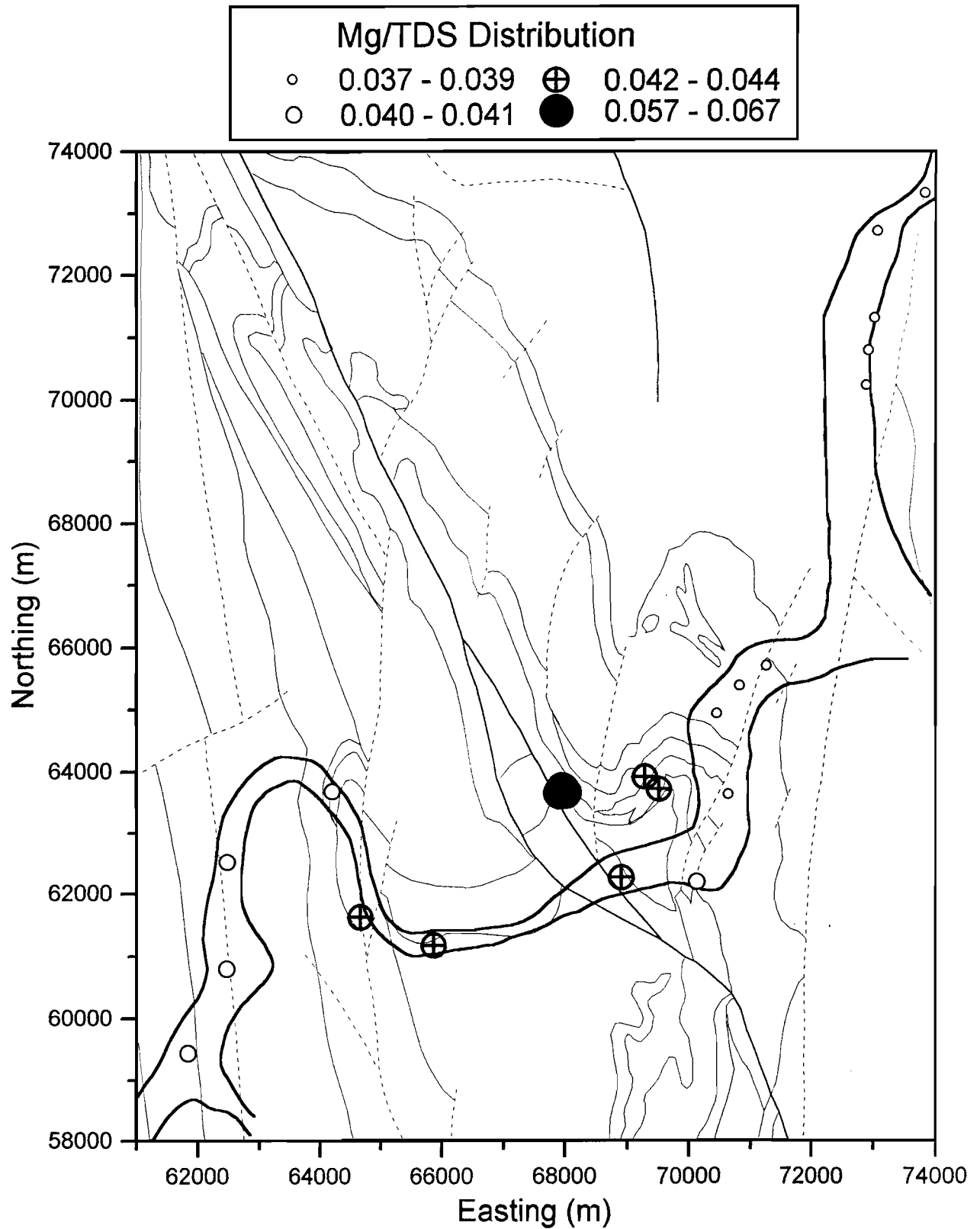


Figure A5.2: Mg/TDS distribution in groundwater at Wollubar.

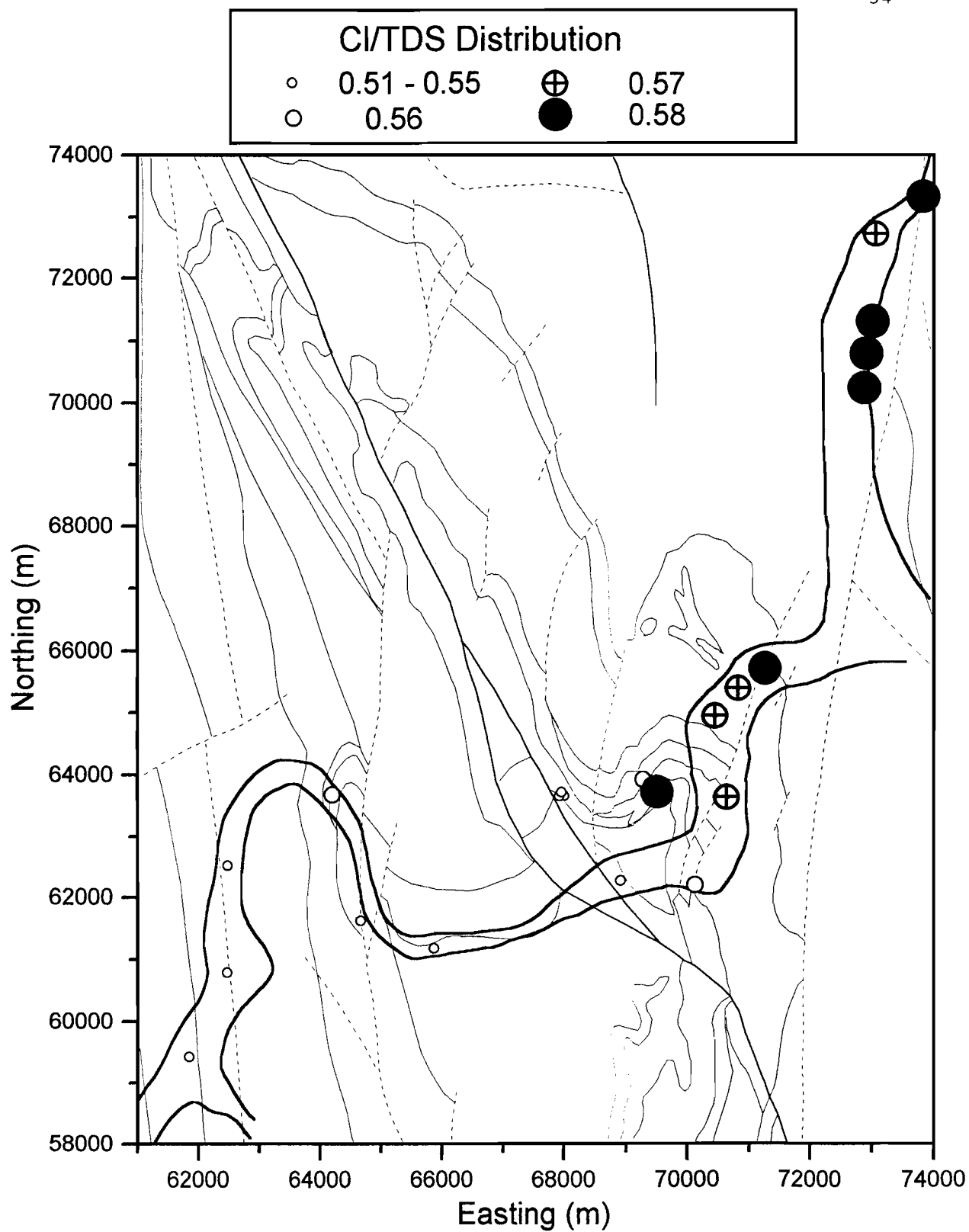


Figure A5.3: Cl/TDS distribution in groundwater at Wollubar.

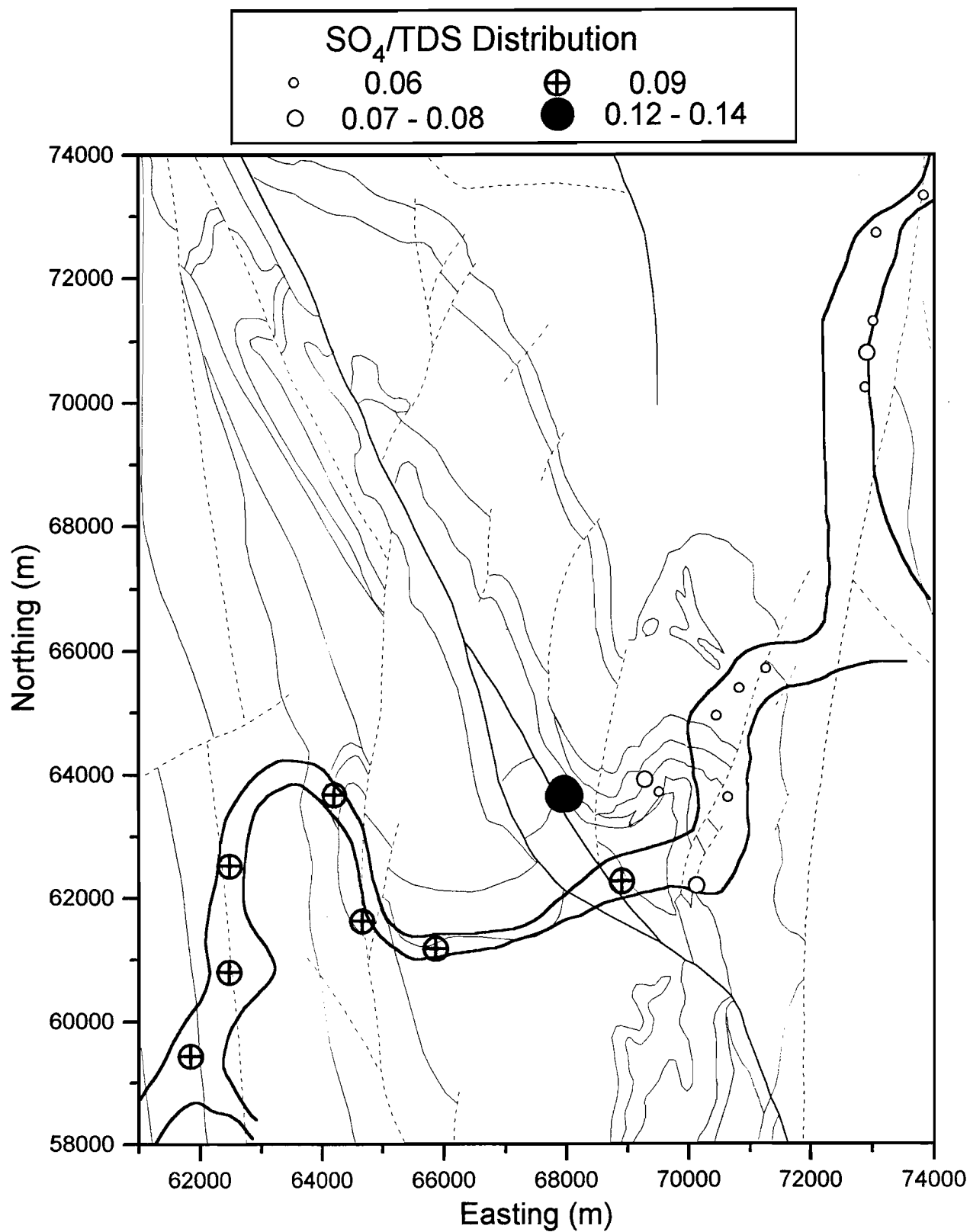


Figure A5.4: SO₄/TDS distribution in groundwater at Wollubar.

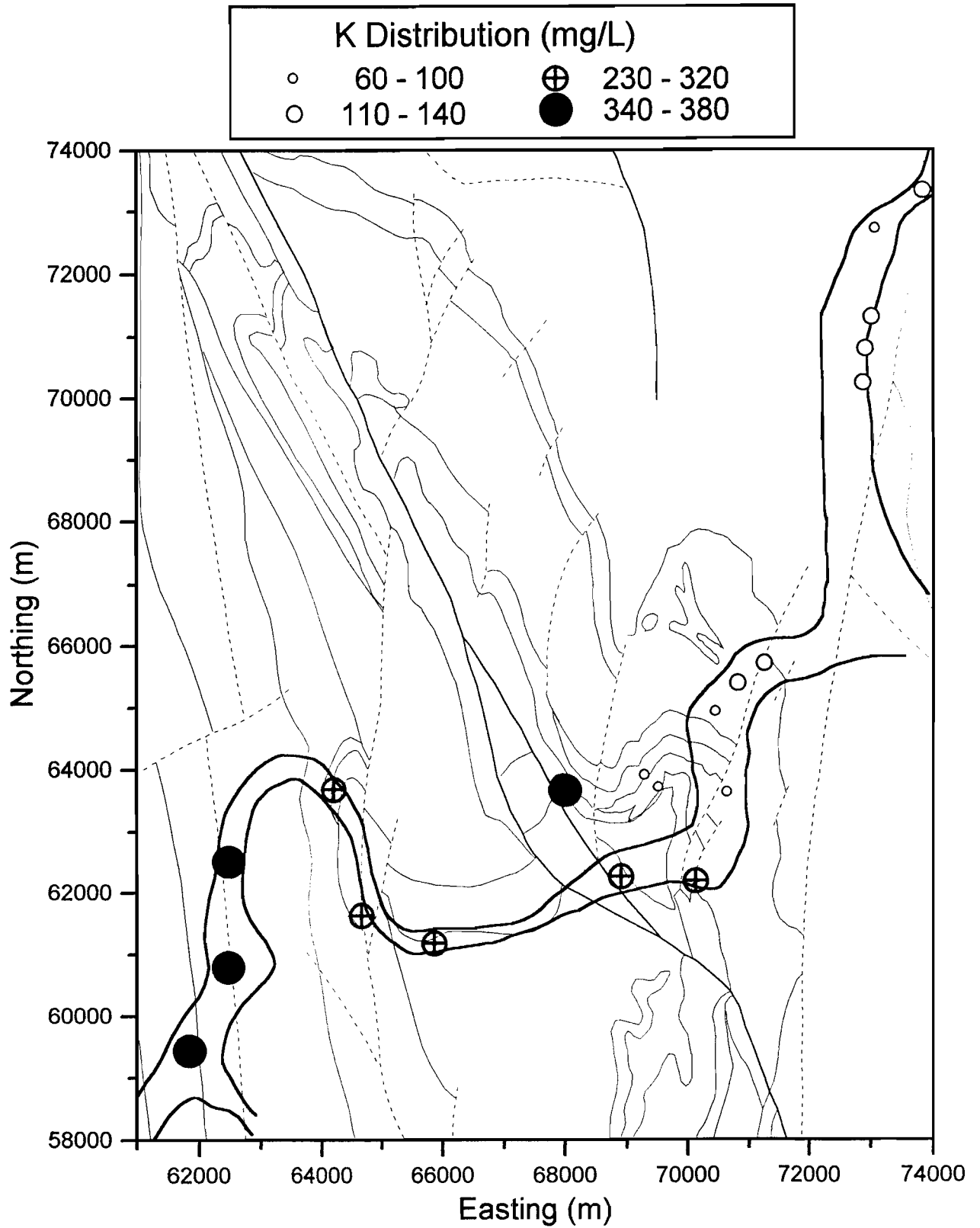


Figure A5.5: Potassium distribution in groundwater at Wollubar.

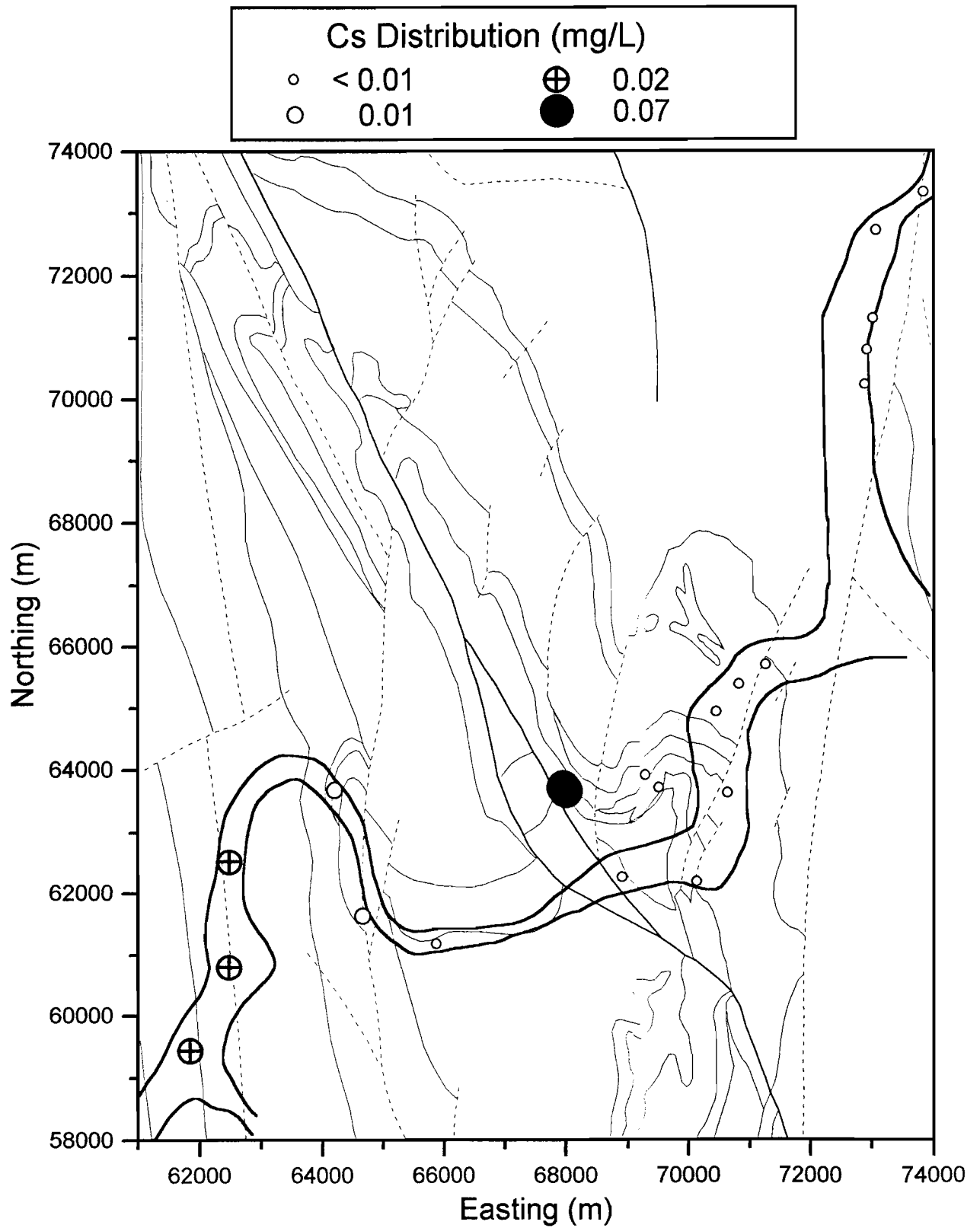


Figure A5.6: Caesium distribution in groundwater at Wollubar.

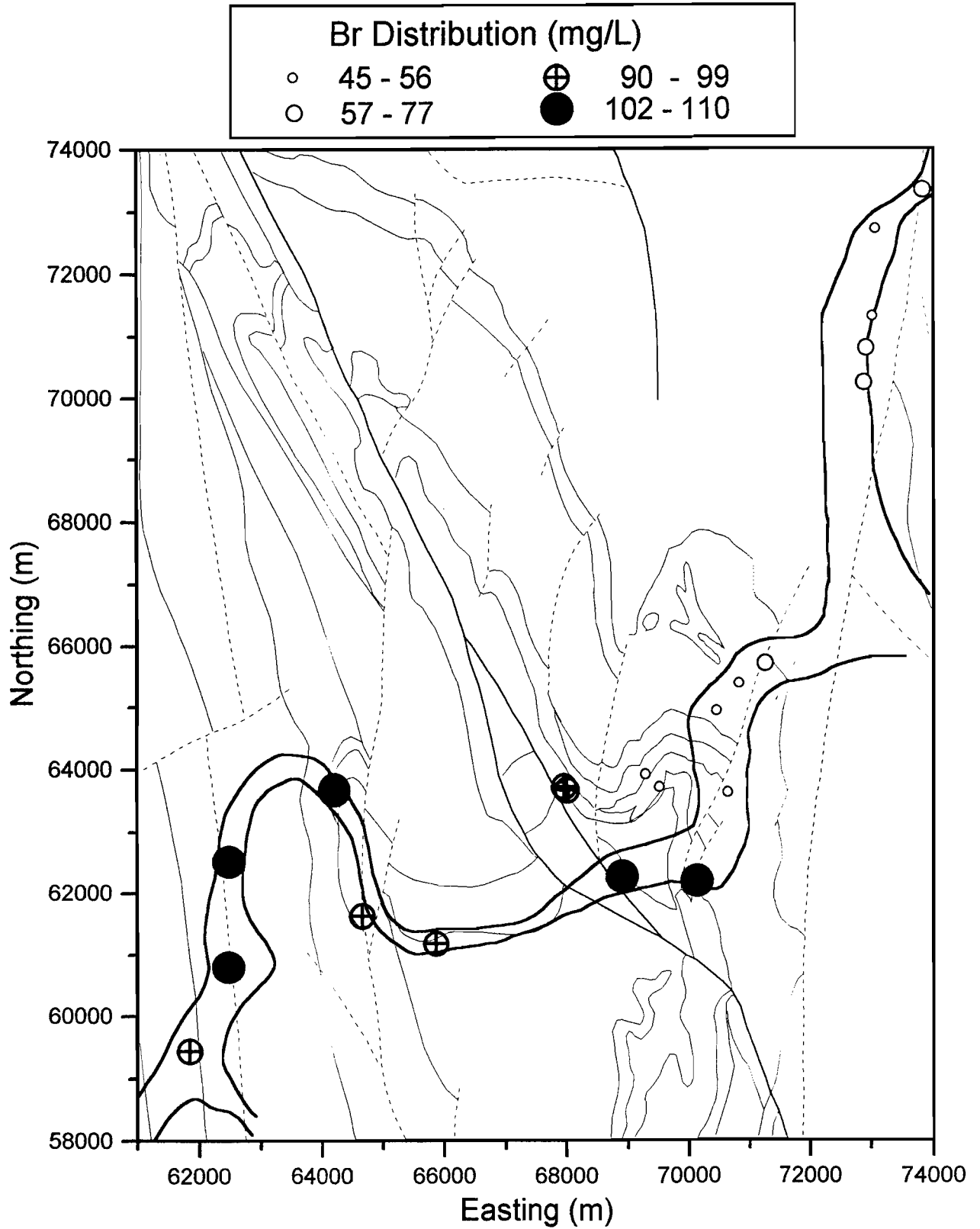


Figure A5.7: Bromide distribution in groundwater at Wollubar.

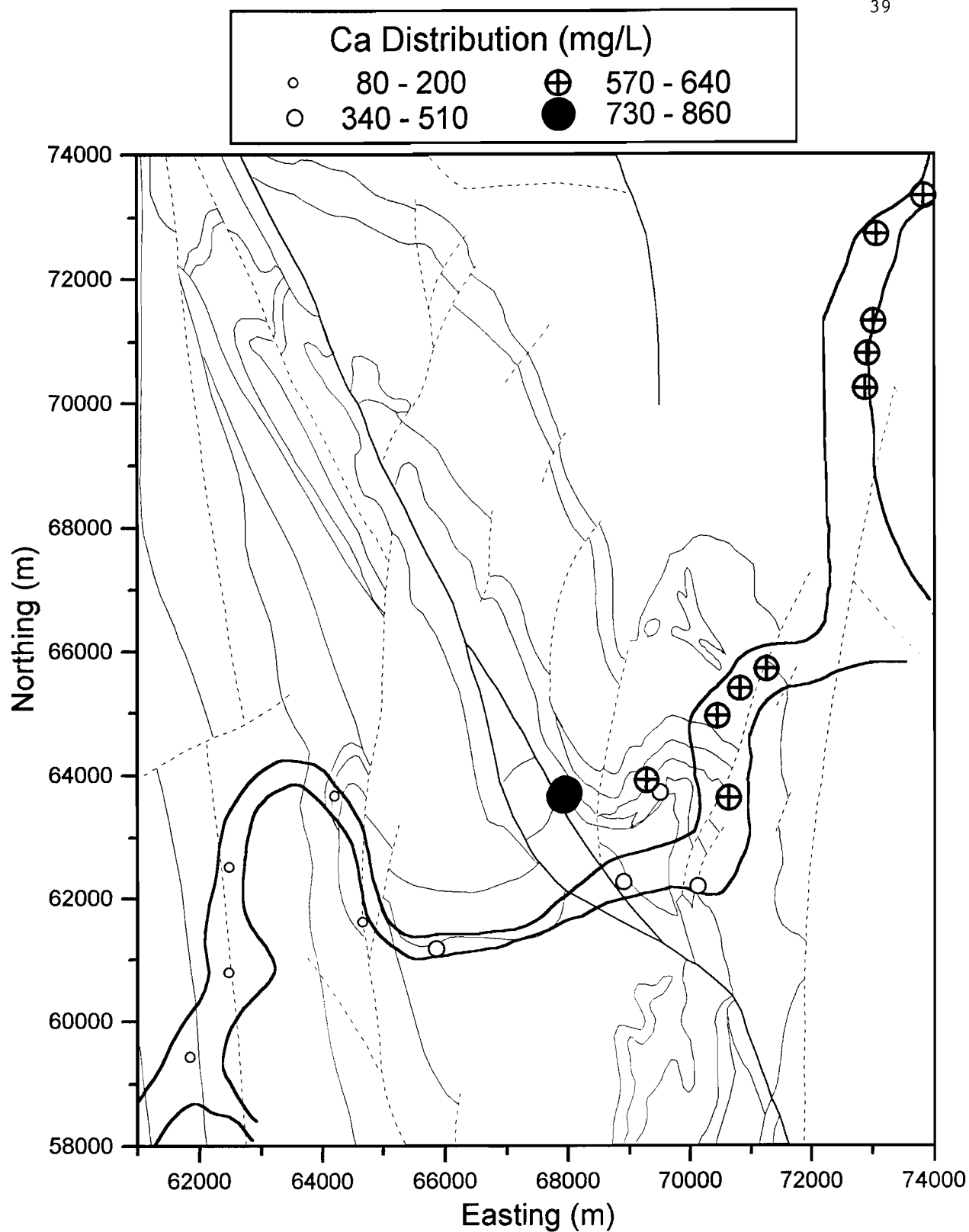


Figure A5.8: Calcium distribution in groundwater at Wollubar.

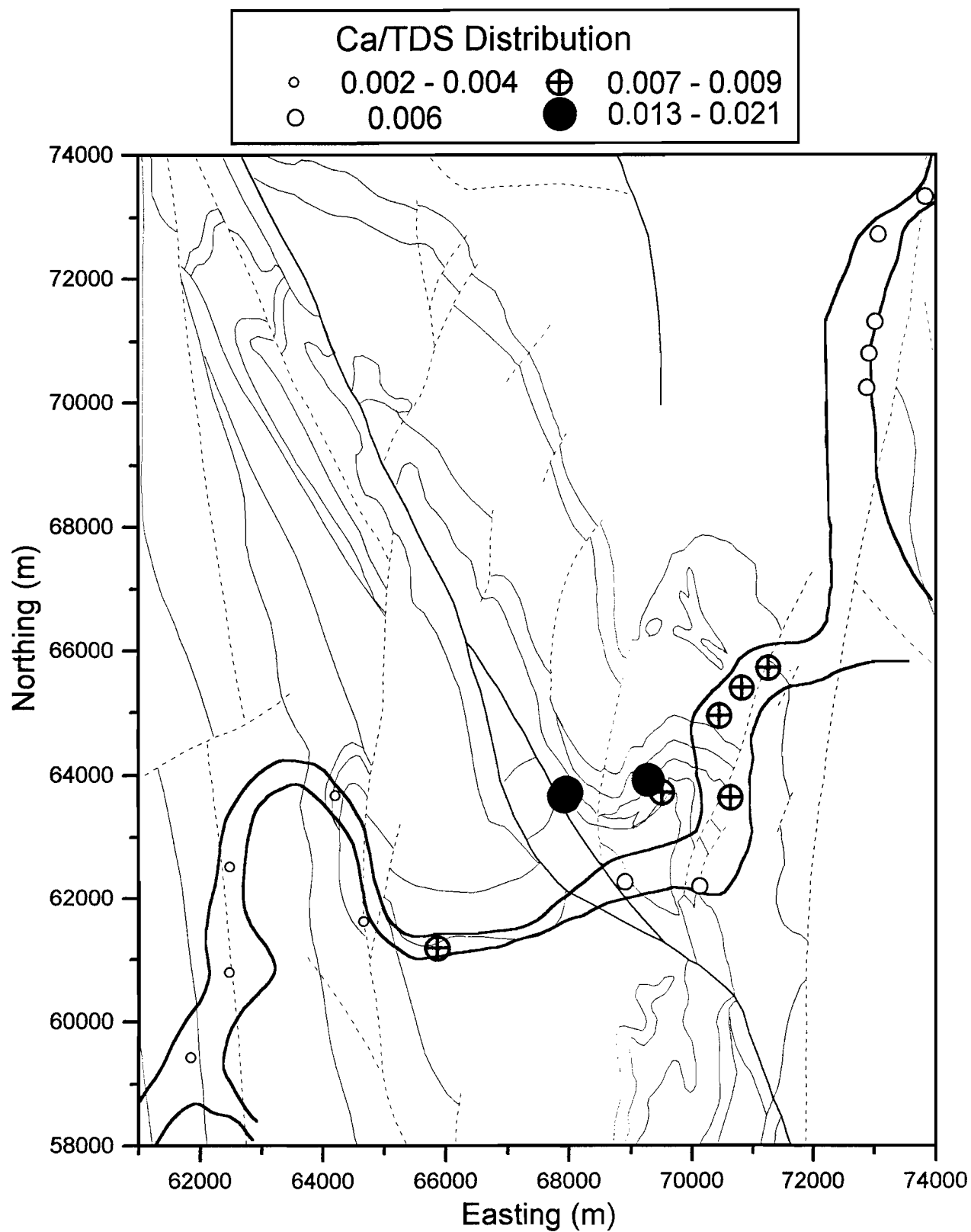


Figure A5.9: Ca/TDS distribution in groundwater at Wollubar.

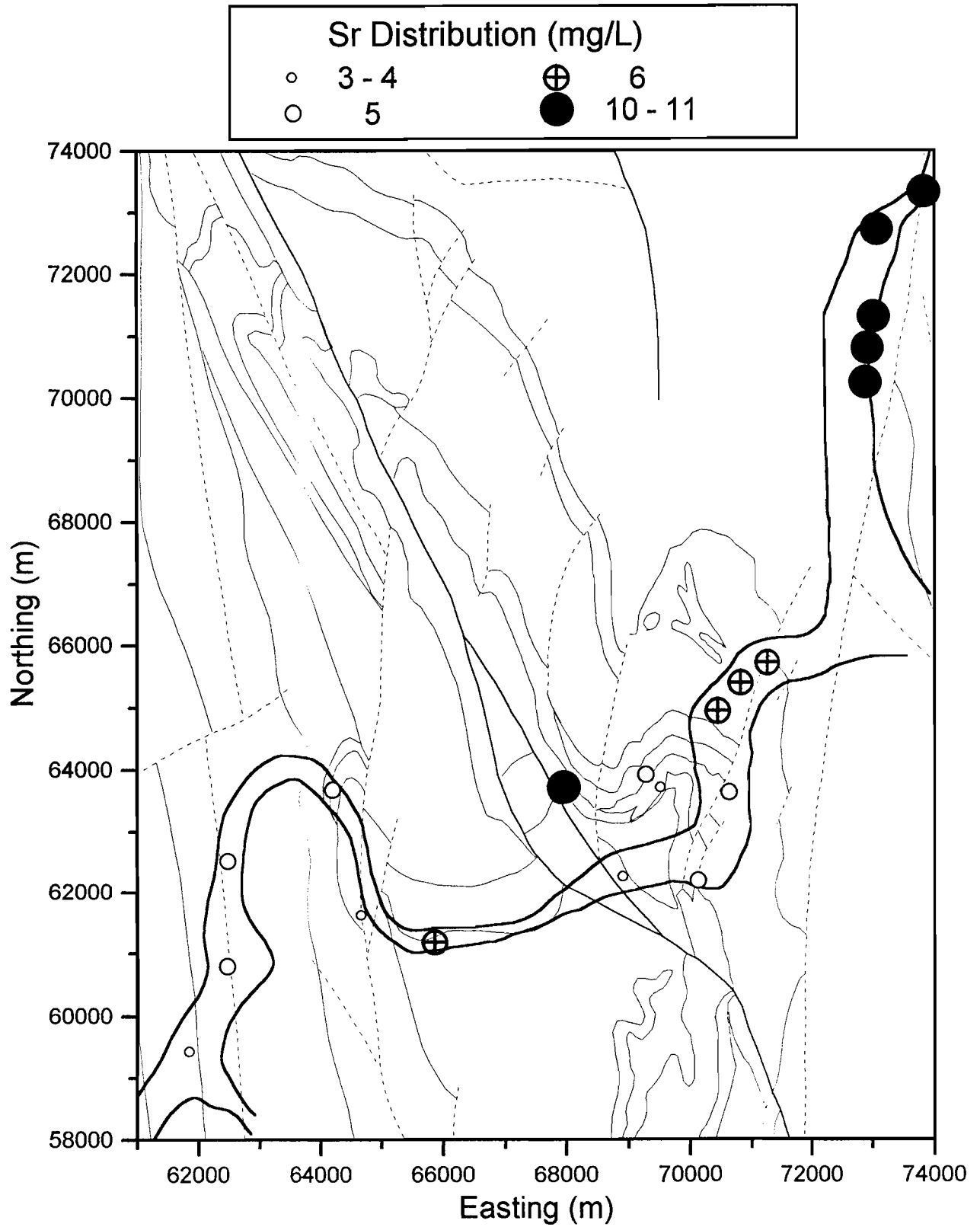


Figure A5.10: Strontium distribution in groundwater at Wollubar.

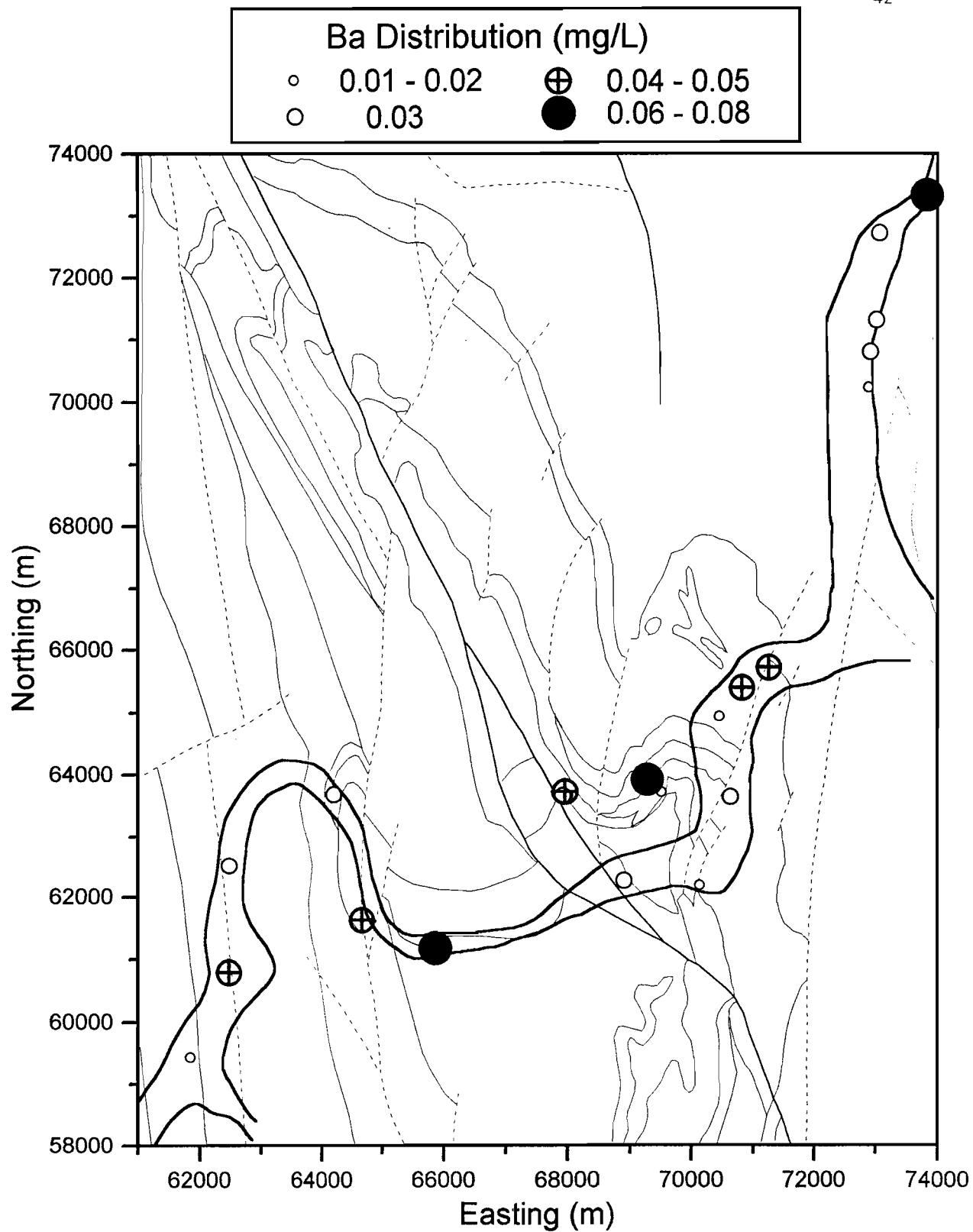


Figure A5.11: Barium distribution in groundwater at Wollubar.

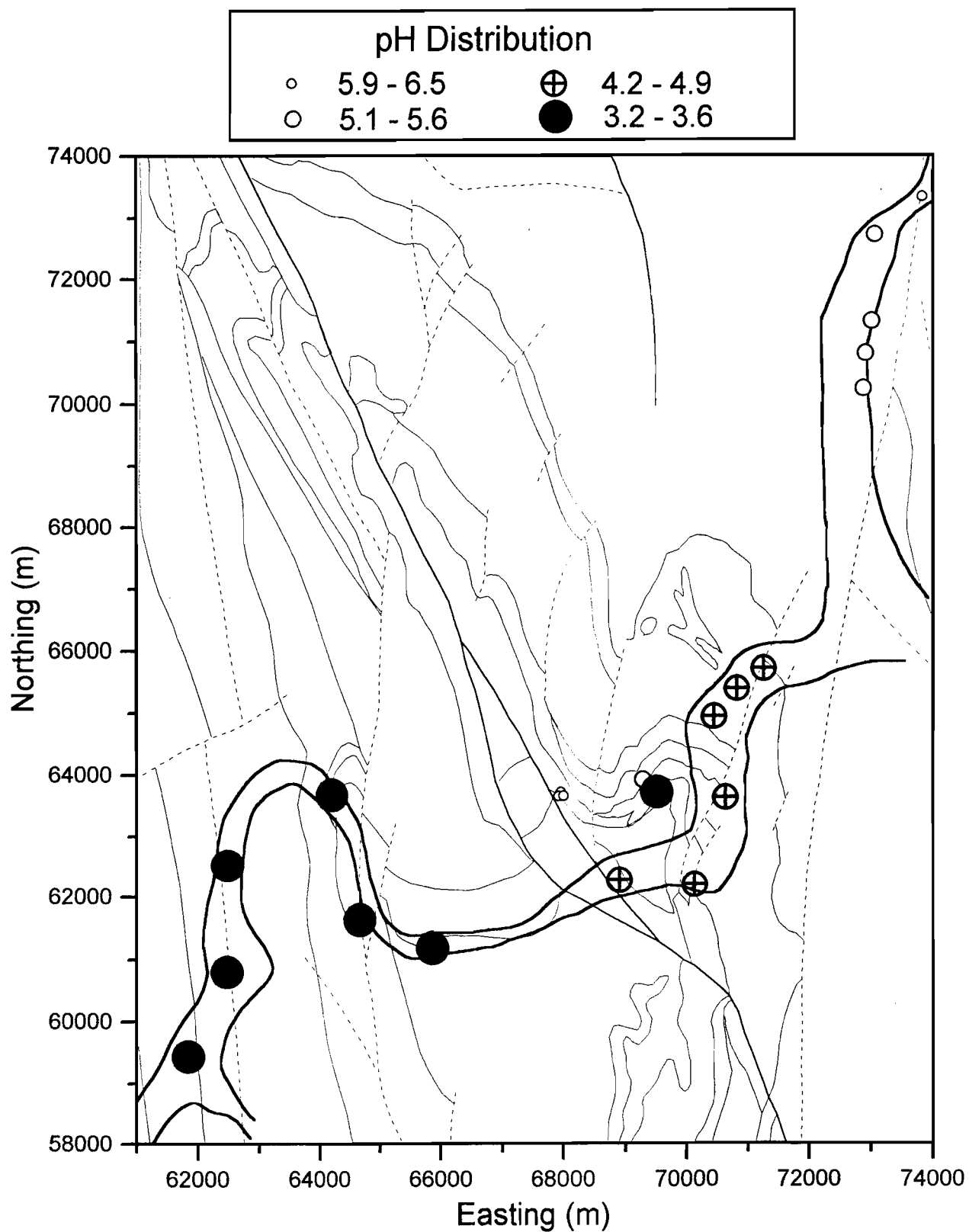


Figure A5.12: pH distribution in groundwater at Wollubar.

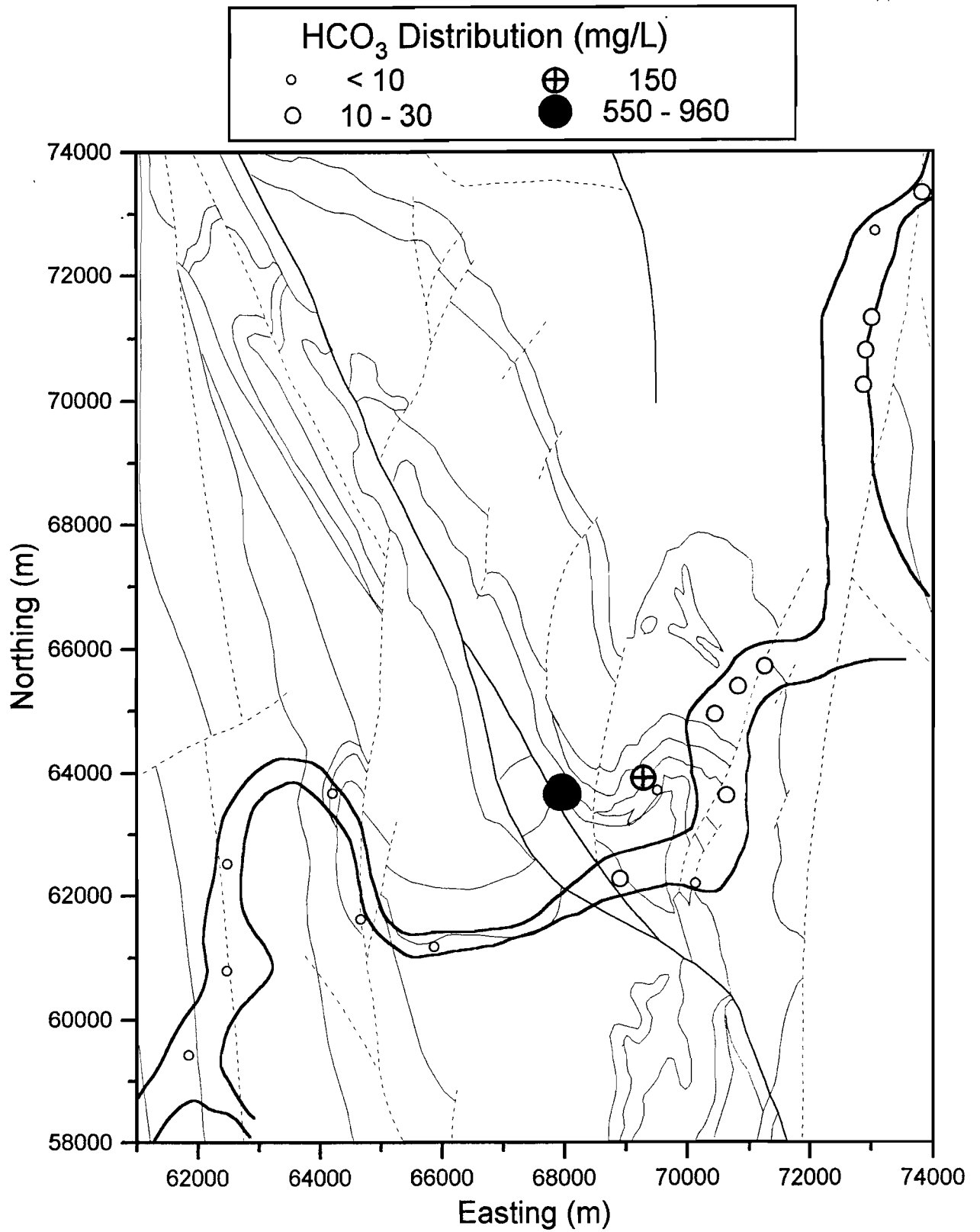


Figure A5.13: Bicarbonate distribution in groundwater at Wollubar.

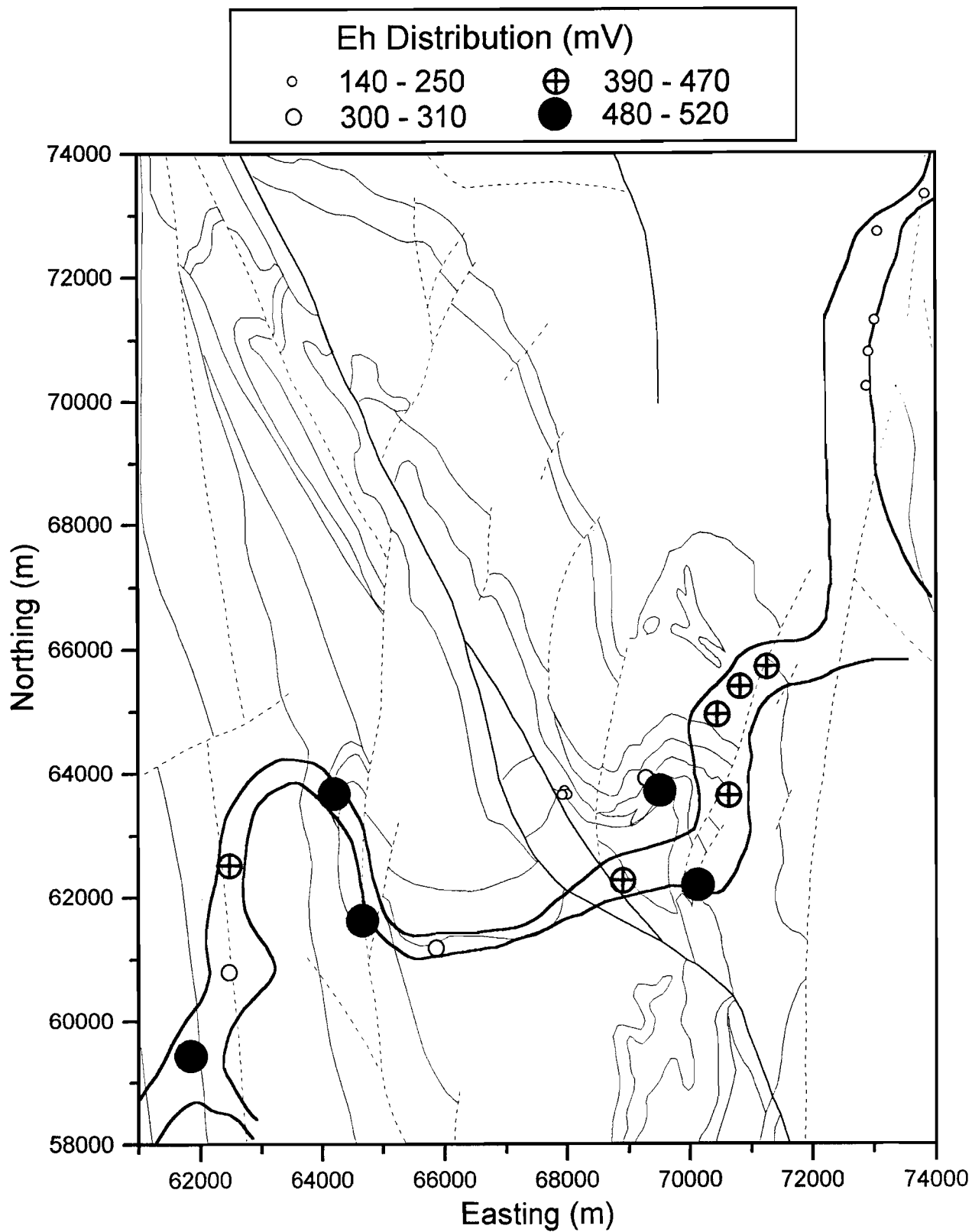


Figure A5.14: Eh distribution in groundwater at Wollubar.

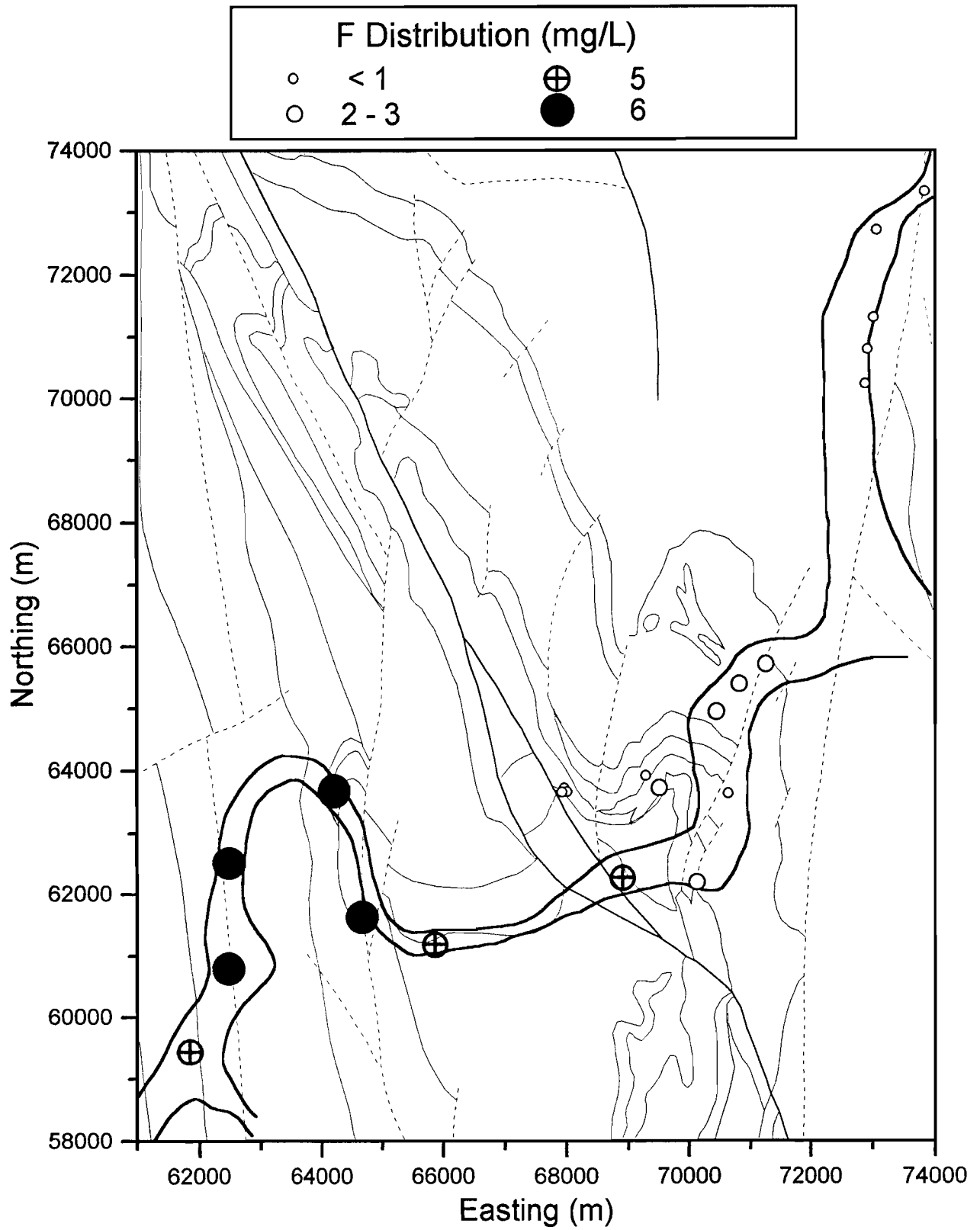


Figure A5.15: Fluoride distribution in groundwater at Wollubar.

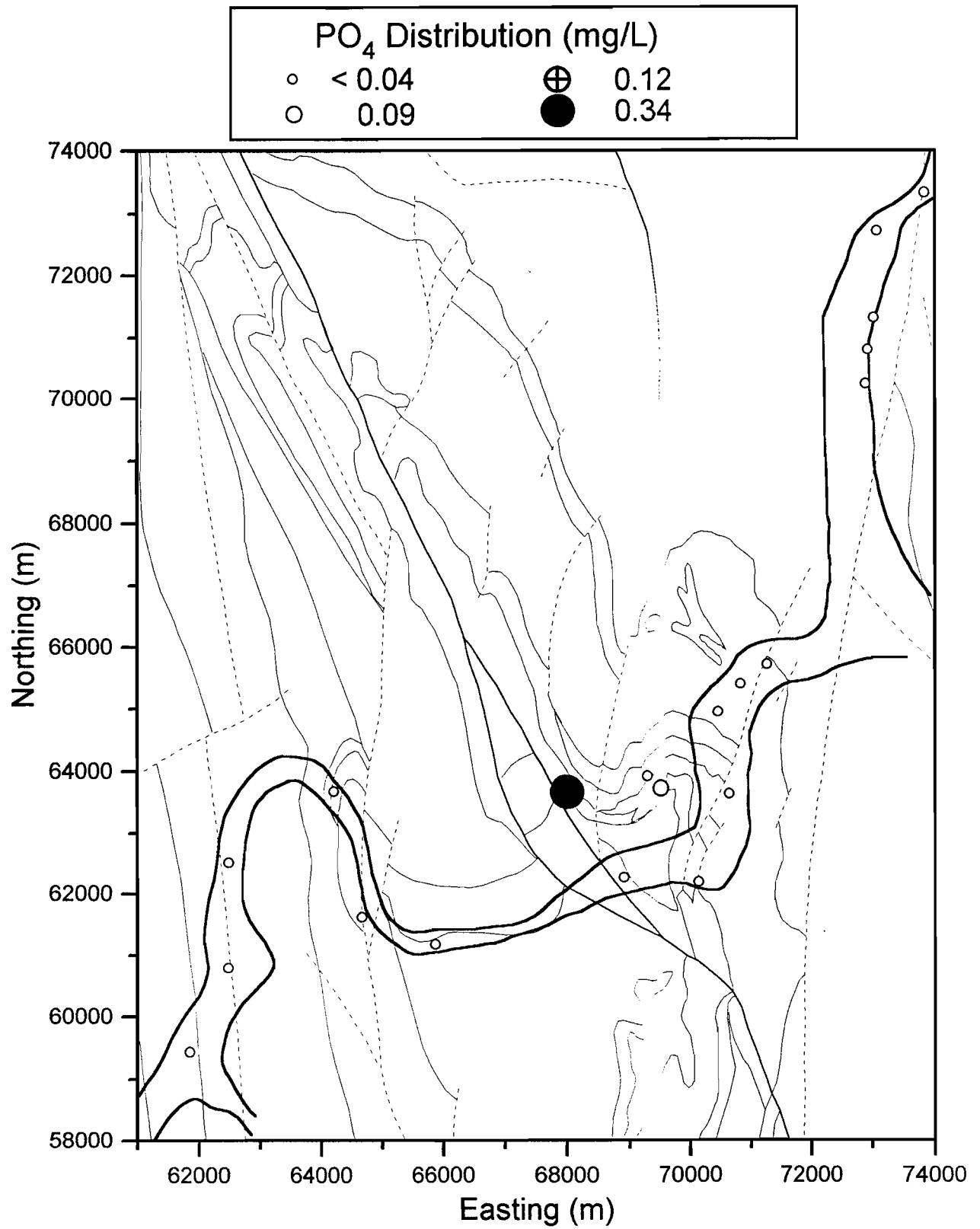


Figure A5.16: Phosphate distribution in groundwater at Wollubar.

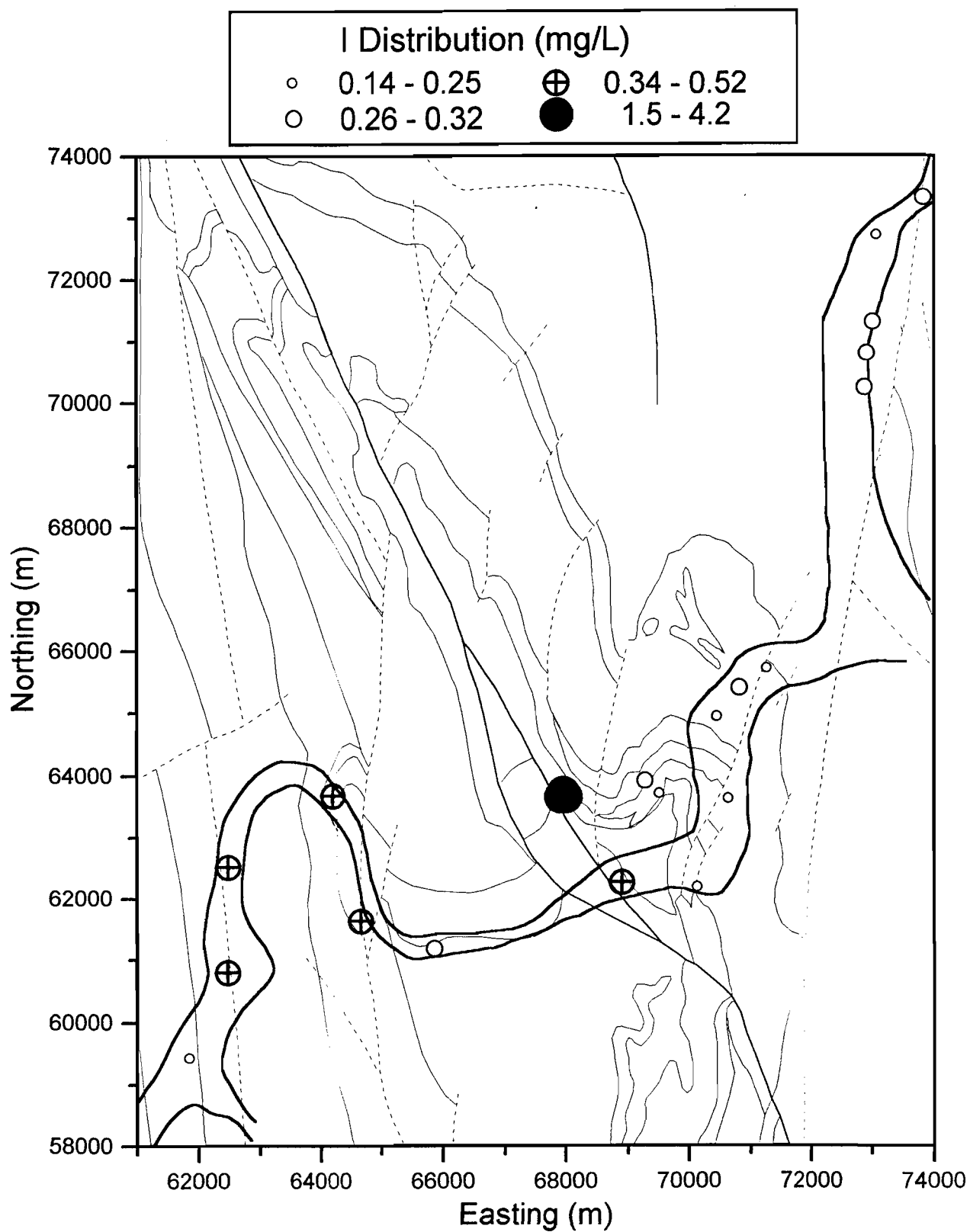


Figure A5.17: Iodide distribution in groundwater at Wollubar.

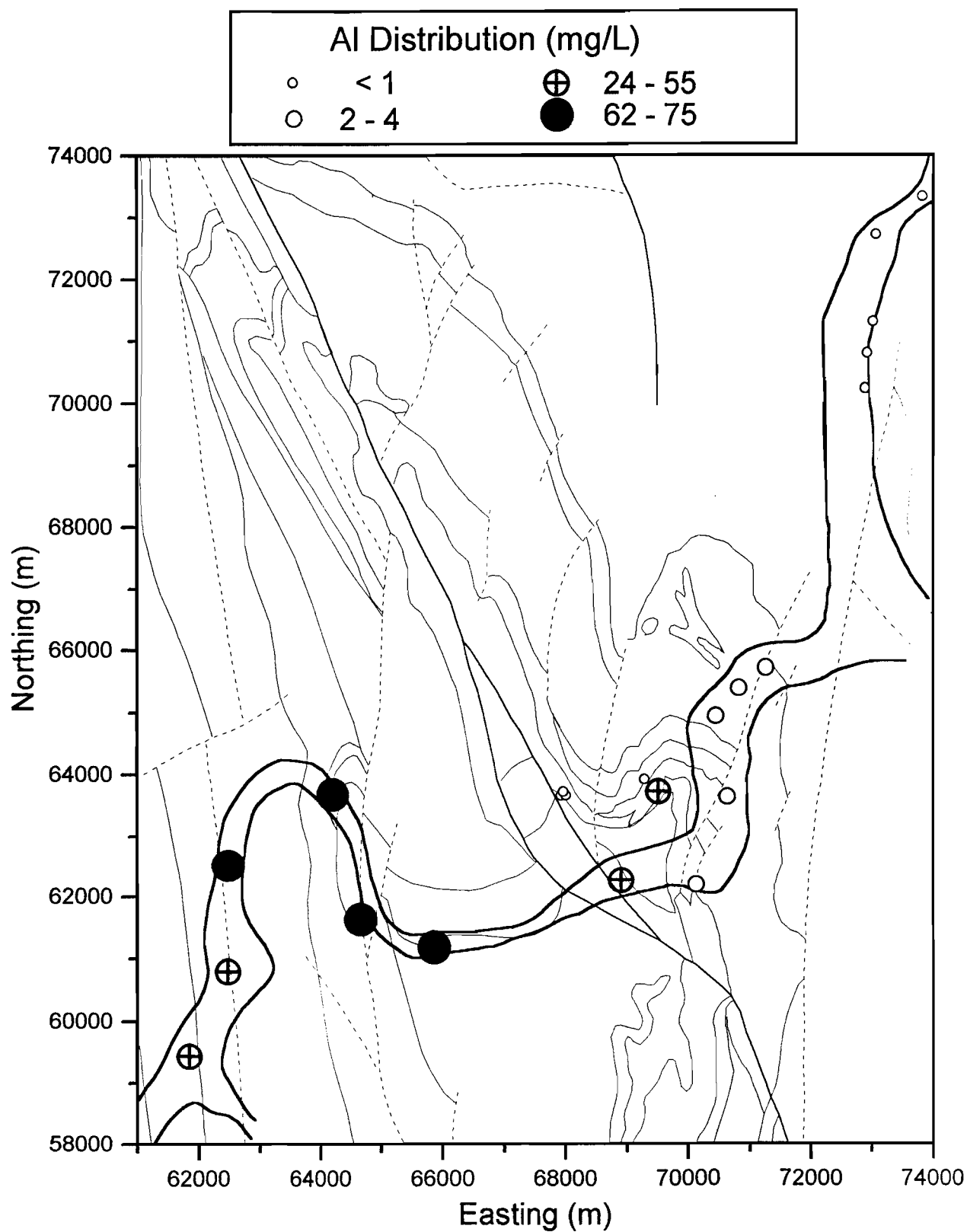


Figure A5.18: Aluminium distribution in groundwater at Wollubar.

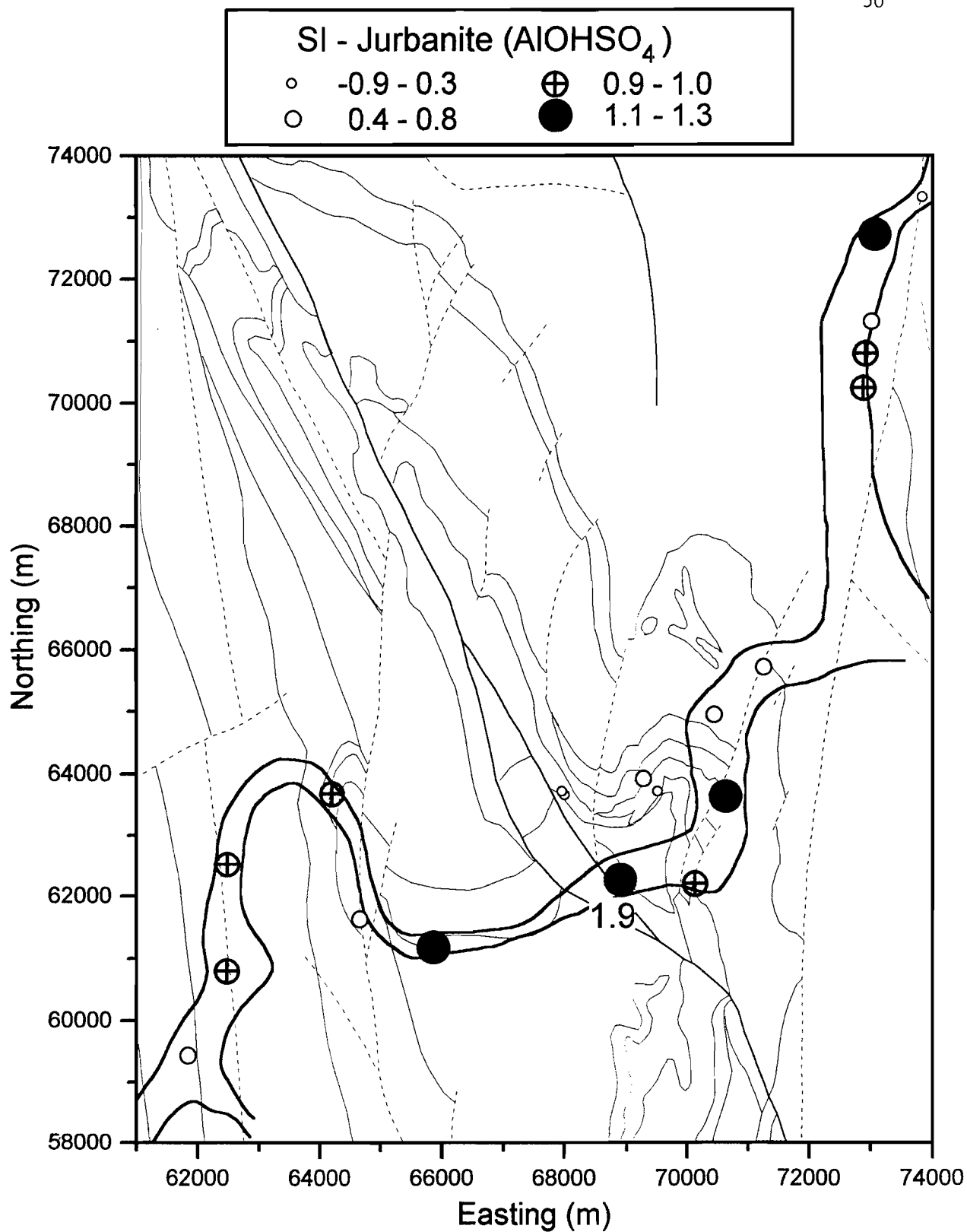


Figure A5.19: Jurbanite SI distribution in groundwater at Wollubar.

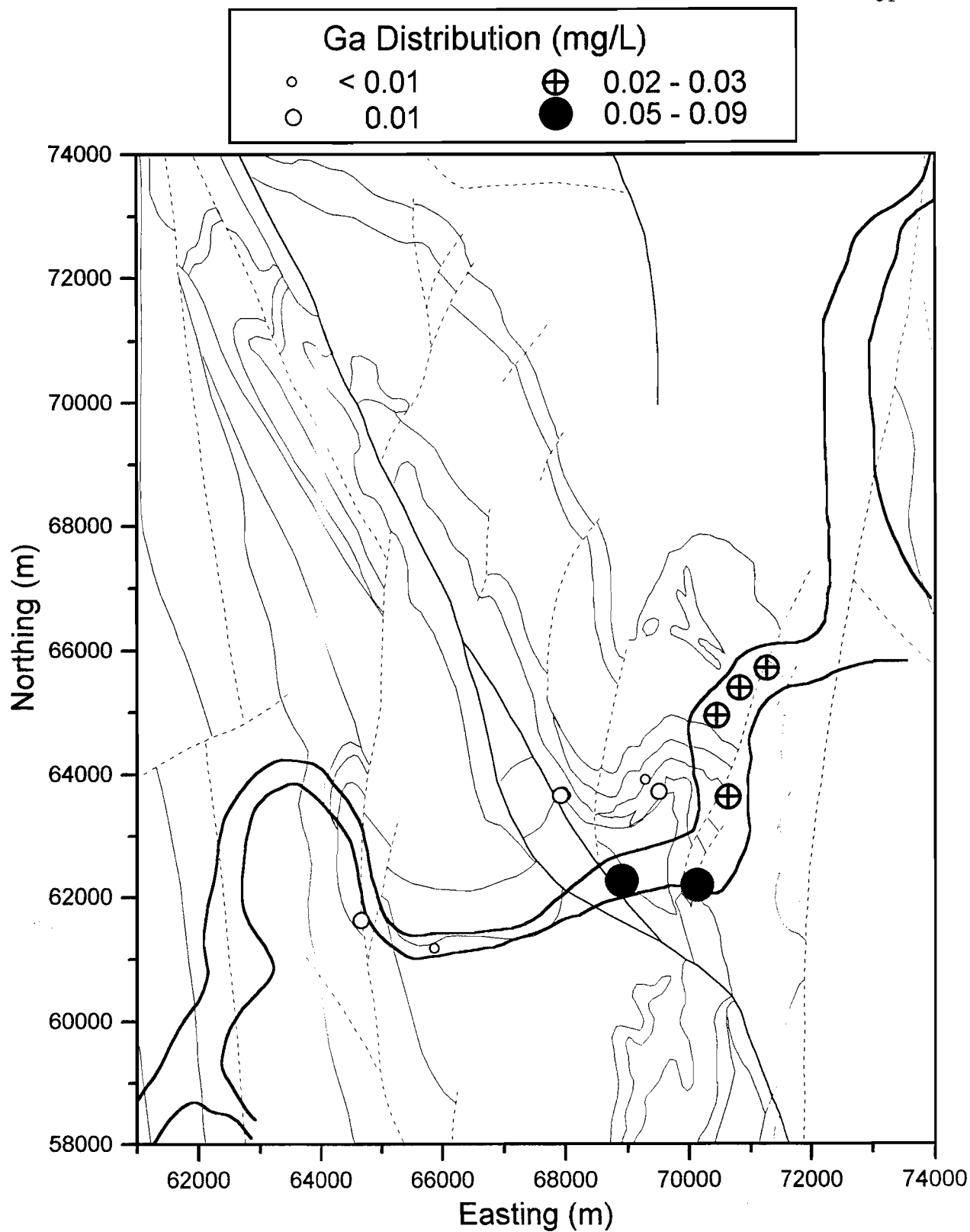


Figure A5.20: Gallium distribution in groundwater at Wollubar.

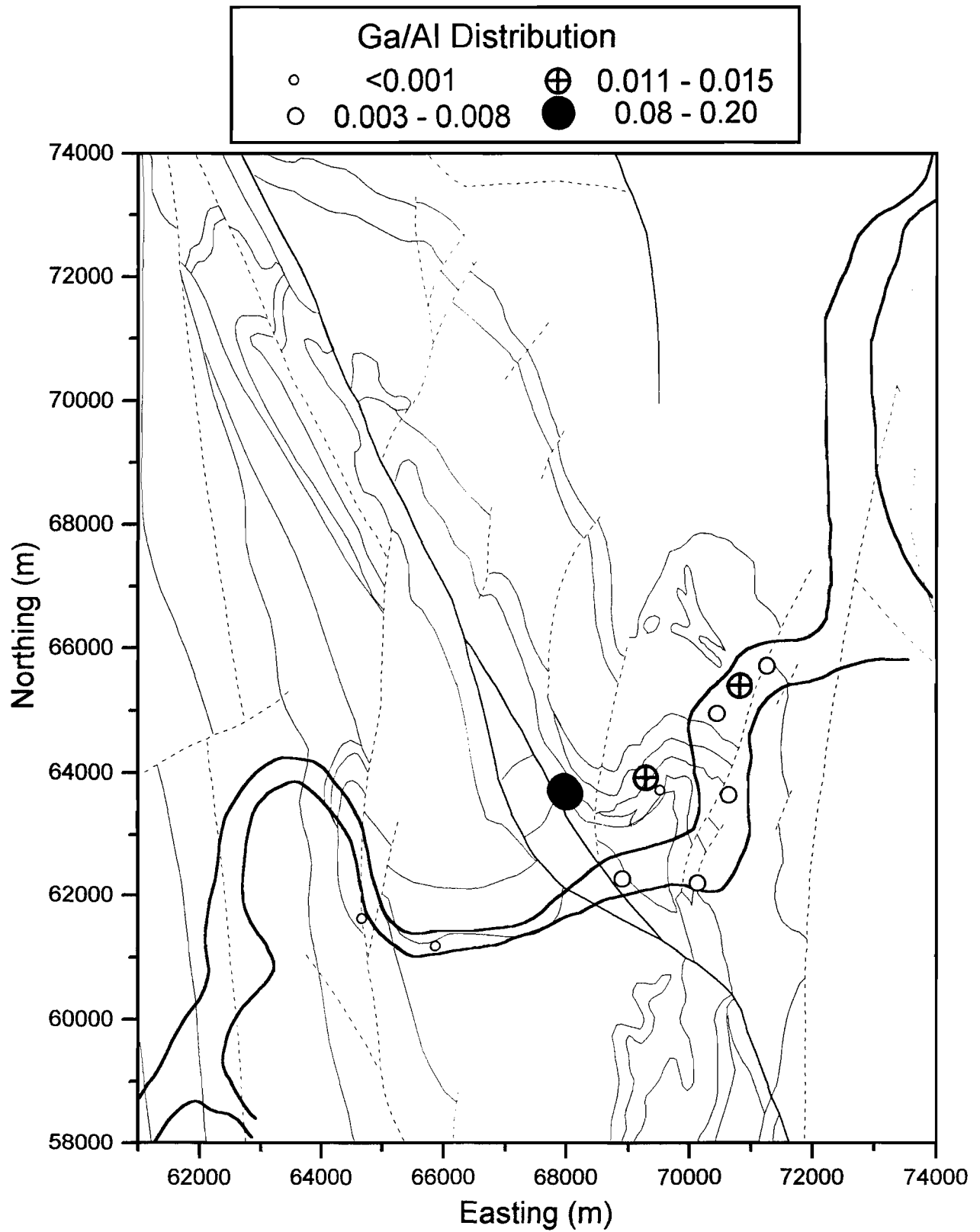


Figure A5.21: Ga/Al distribution in groundwater at Wollubar.

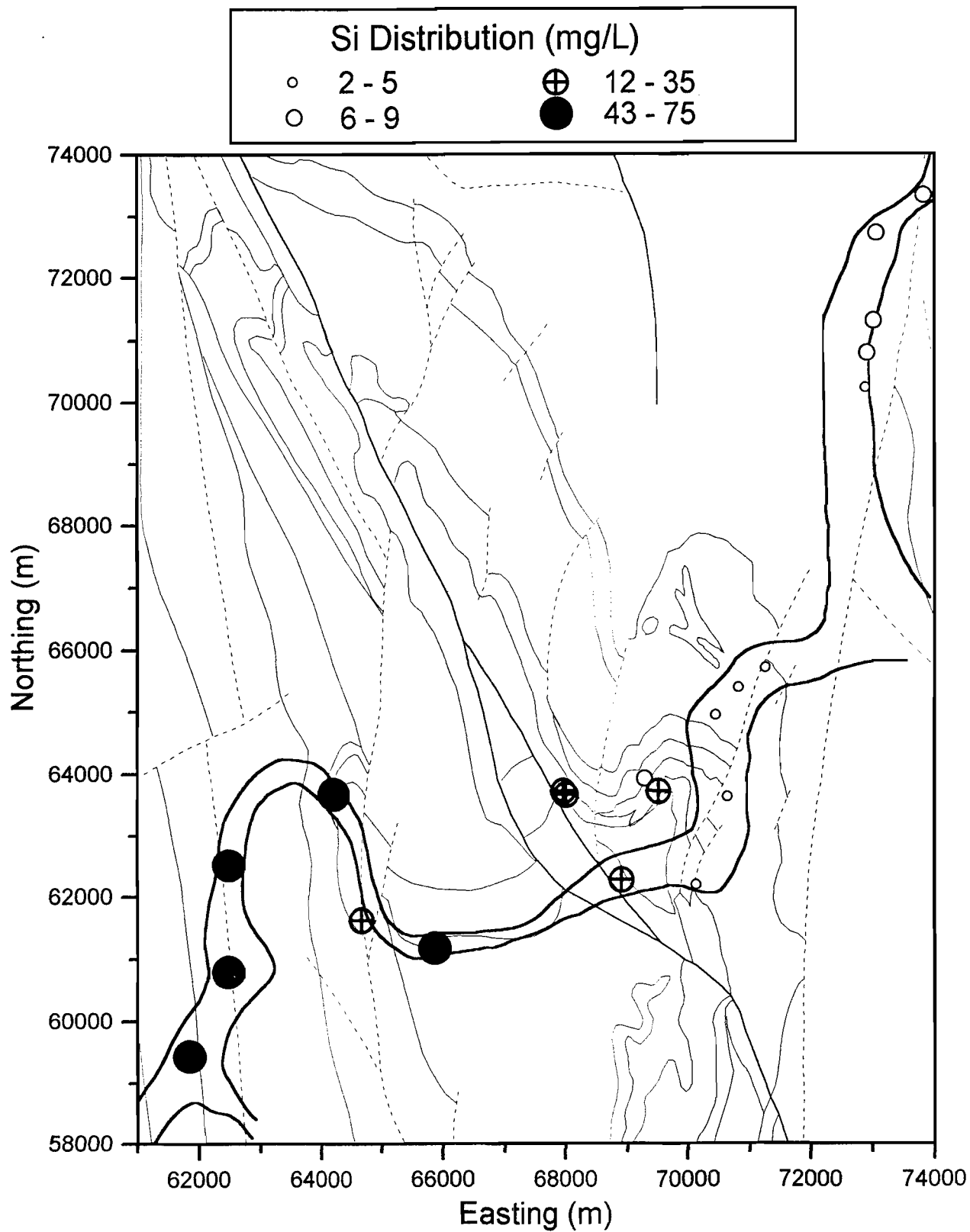


Figure A5.22: Silicon distribution in groundwater at Wollubar.

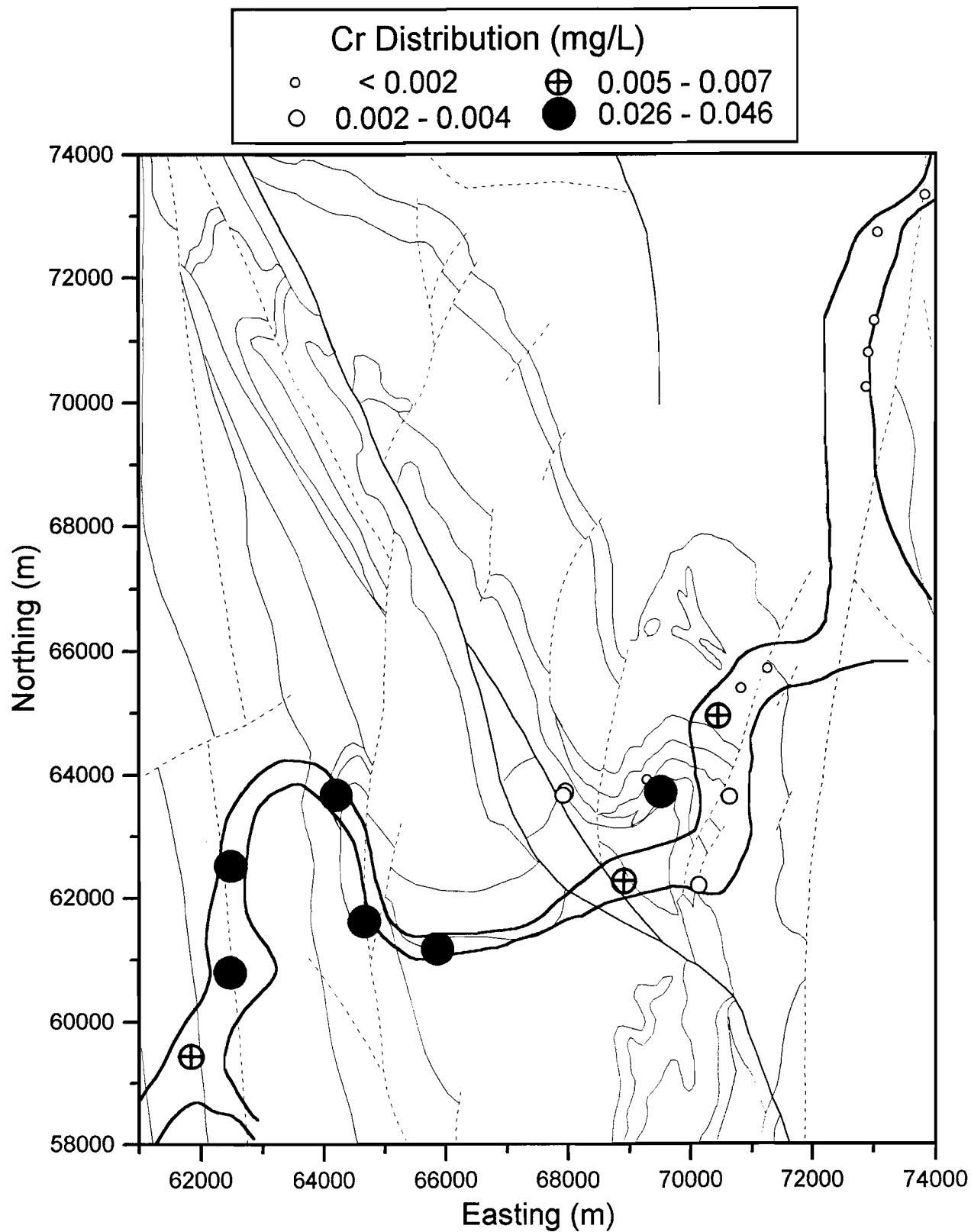


Figure A5.23: Chromium distribution in groundwater at Wollubar.

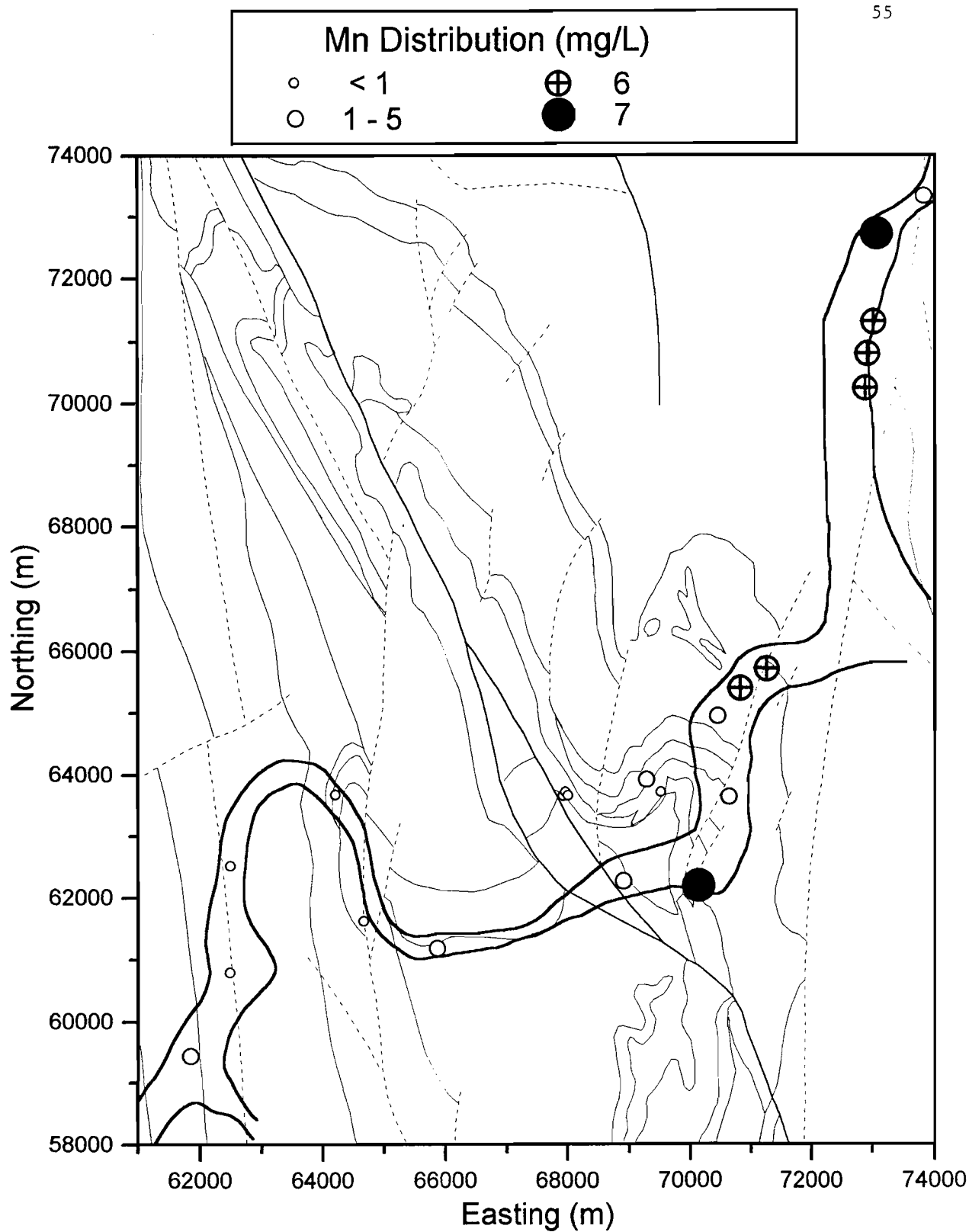


Figure A5.24: Manganese distribution in groundwater at Wollubar.

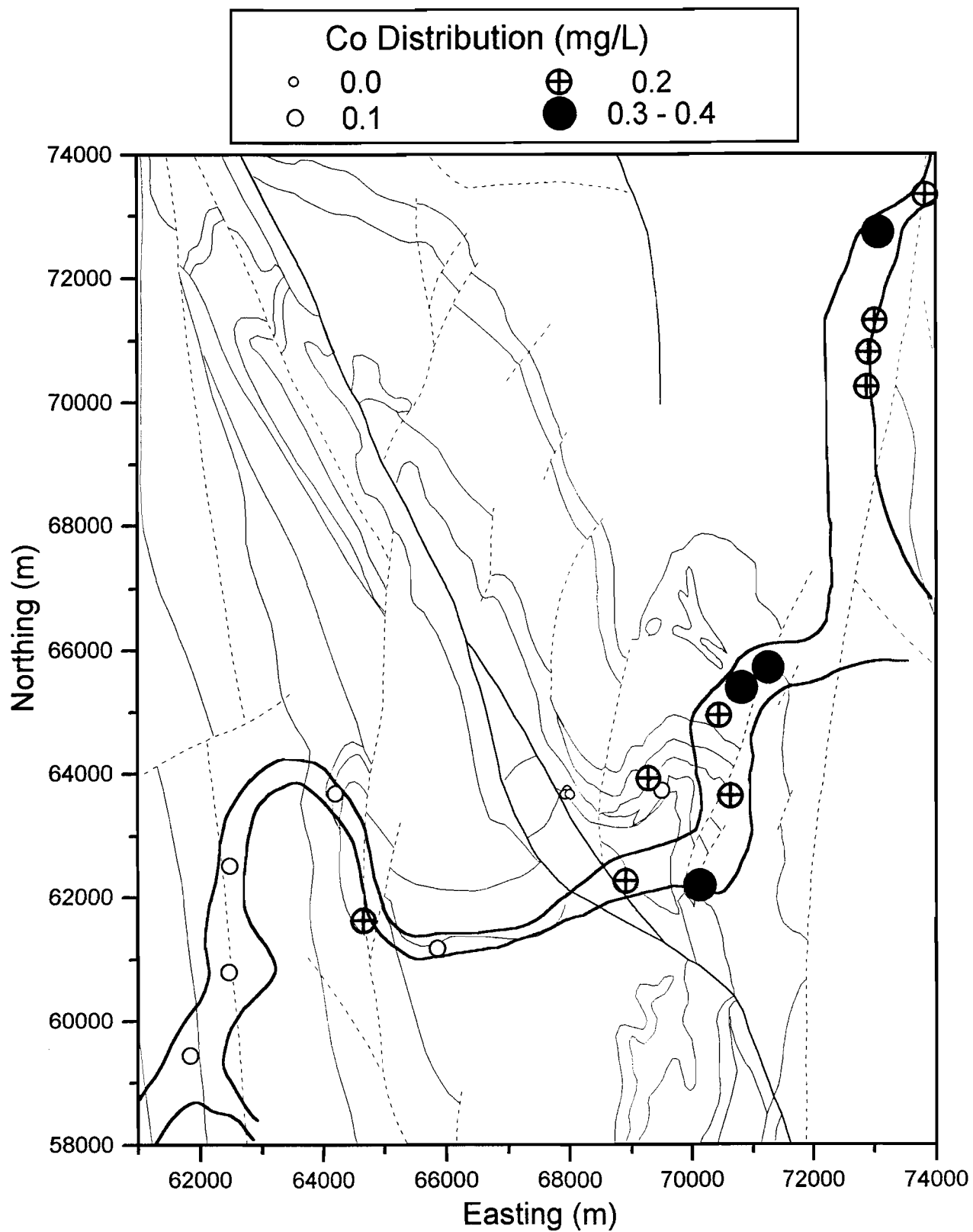


Figure A5.25: Cobalt distribution in groundwater at Wollubar.

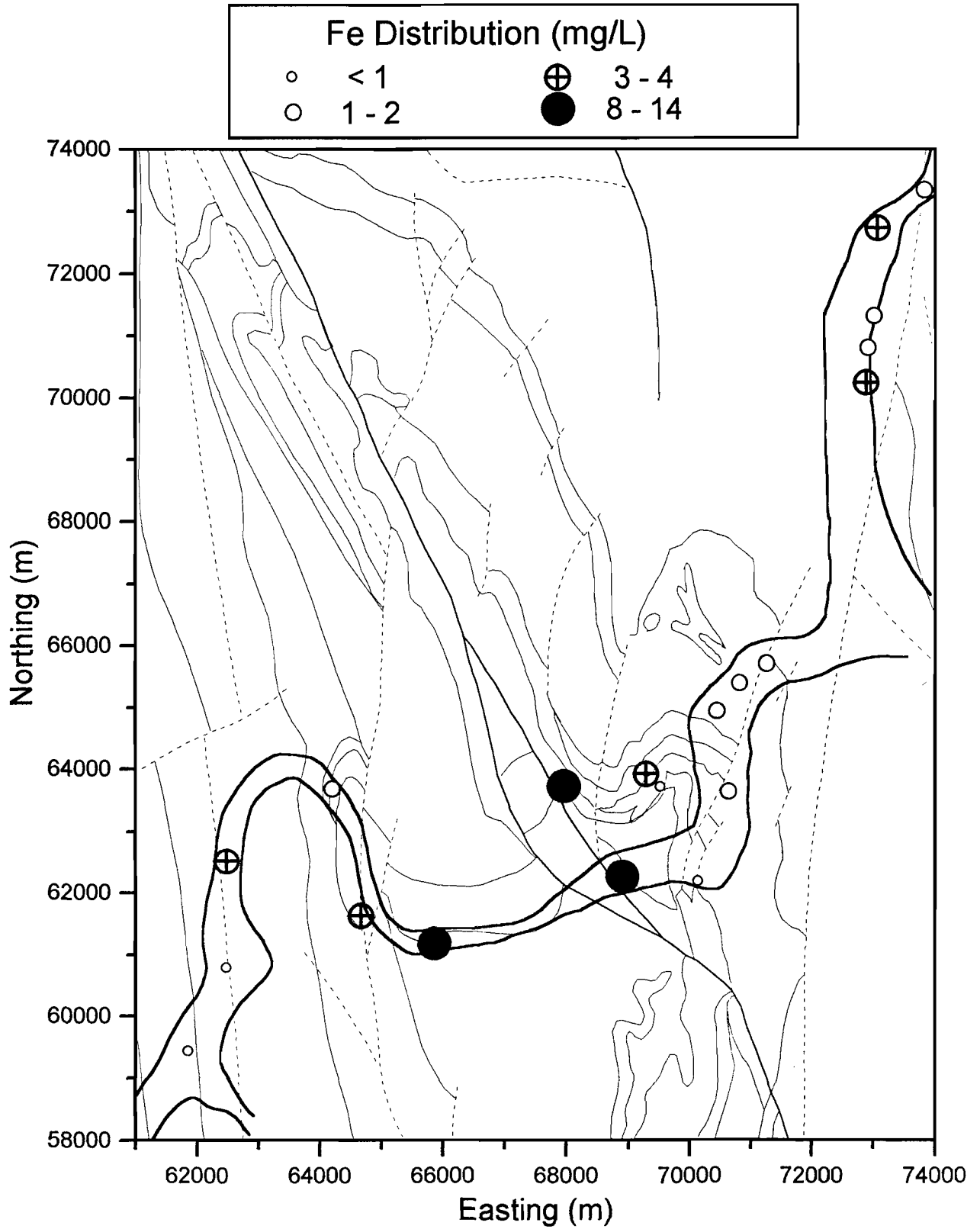


Figure A5.26: Iron distribution in groundwater at Wollubar.

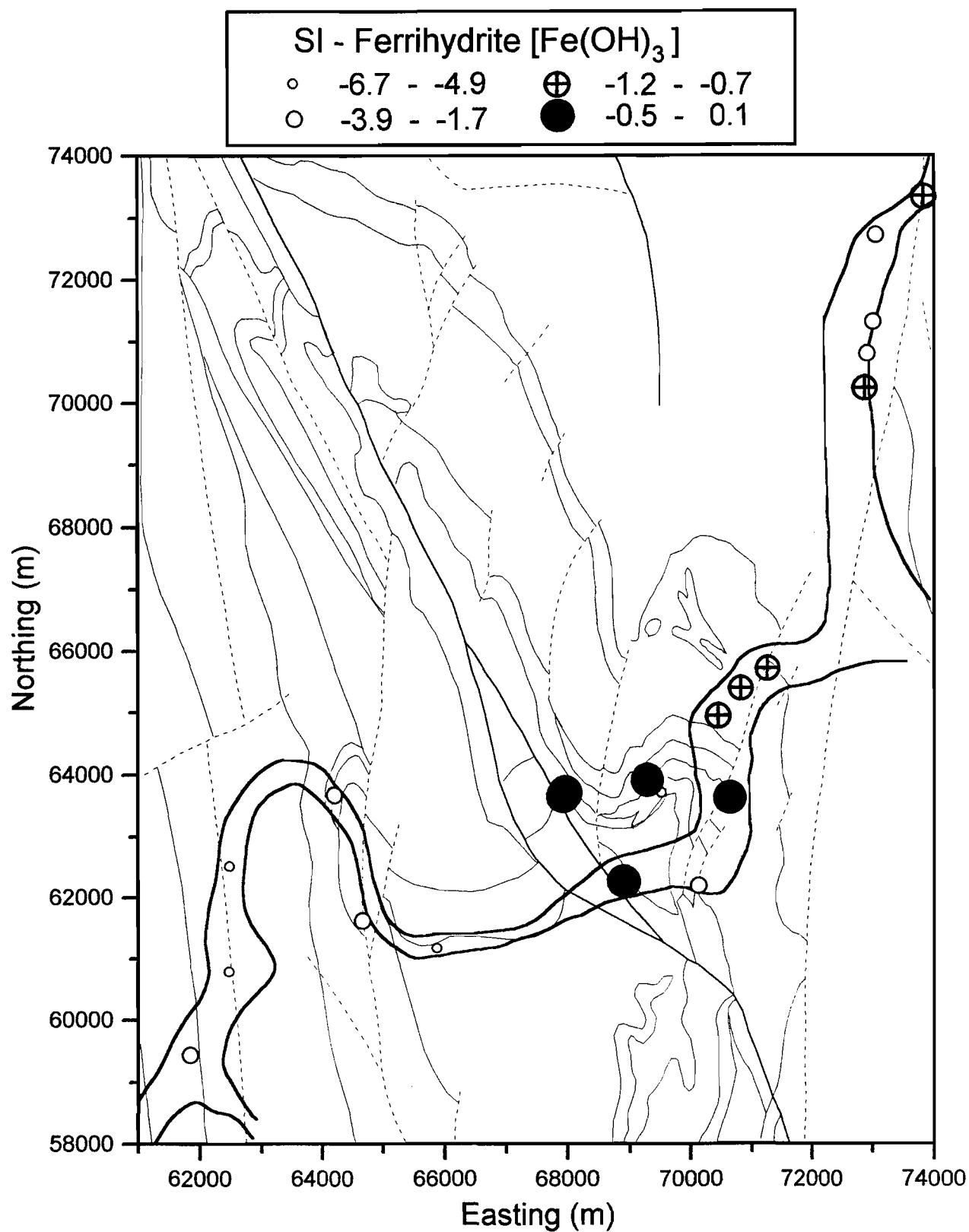


Figure A5.27: Ferrihydrite SI distribution in groundwater at Wollubar.

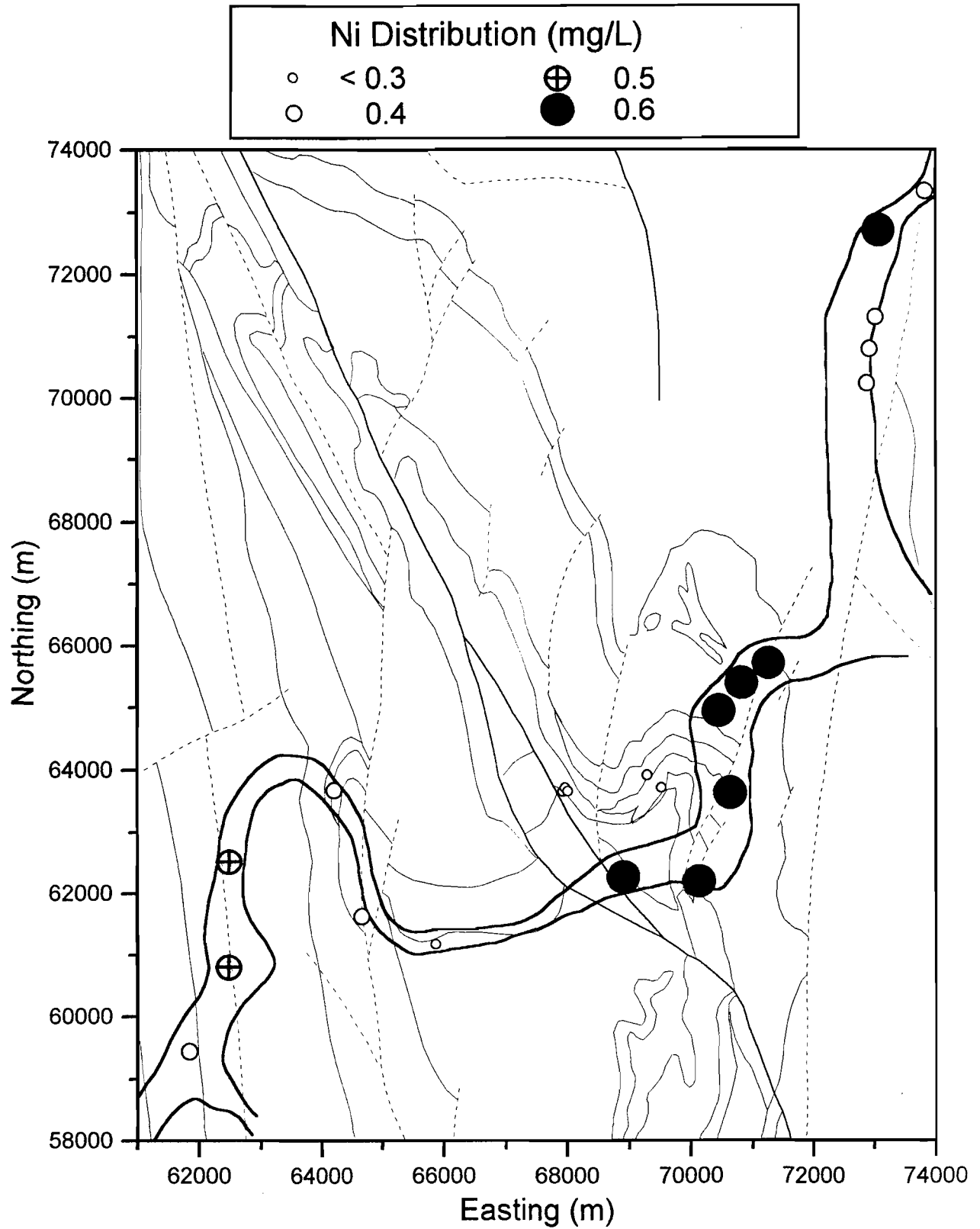


Figure A5.28: Nickel distribution in groundwater at Wollubar.

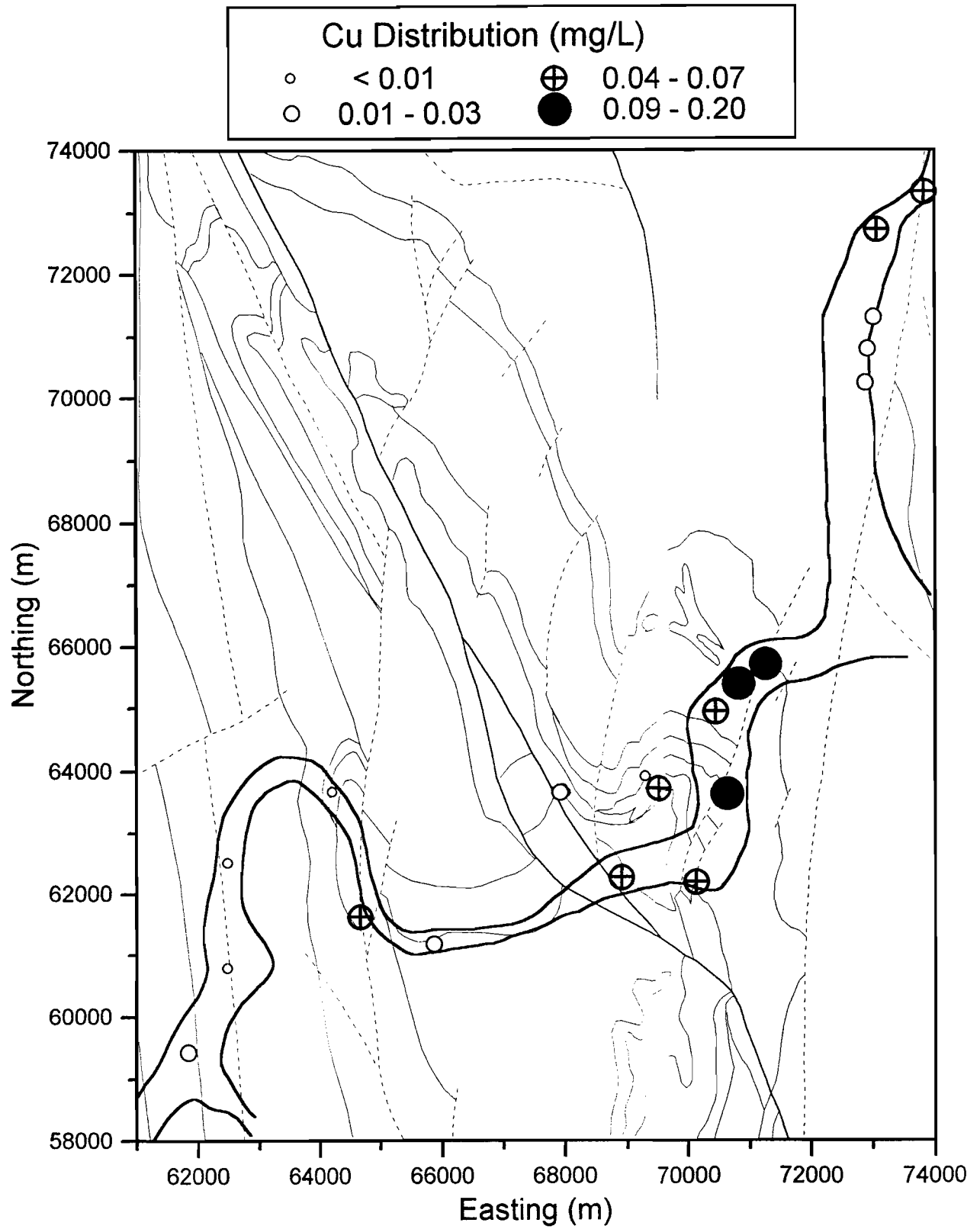


Figure A5.29: Copper distribution in groundwater at Wollubar.

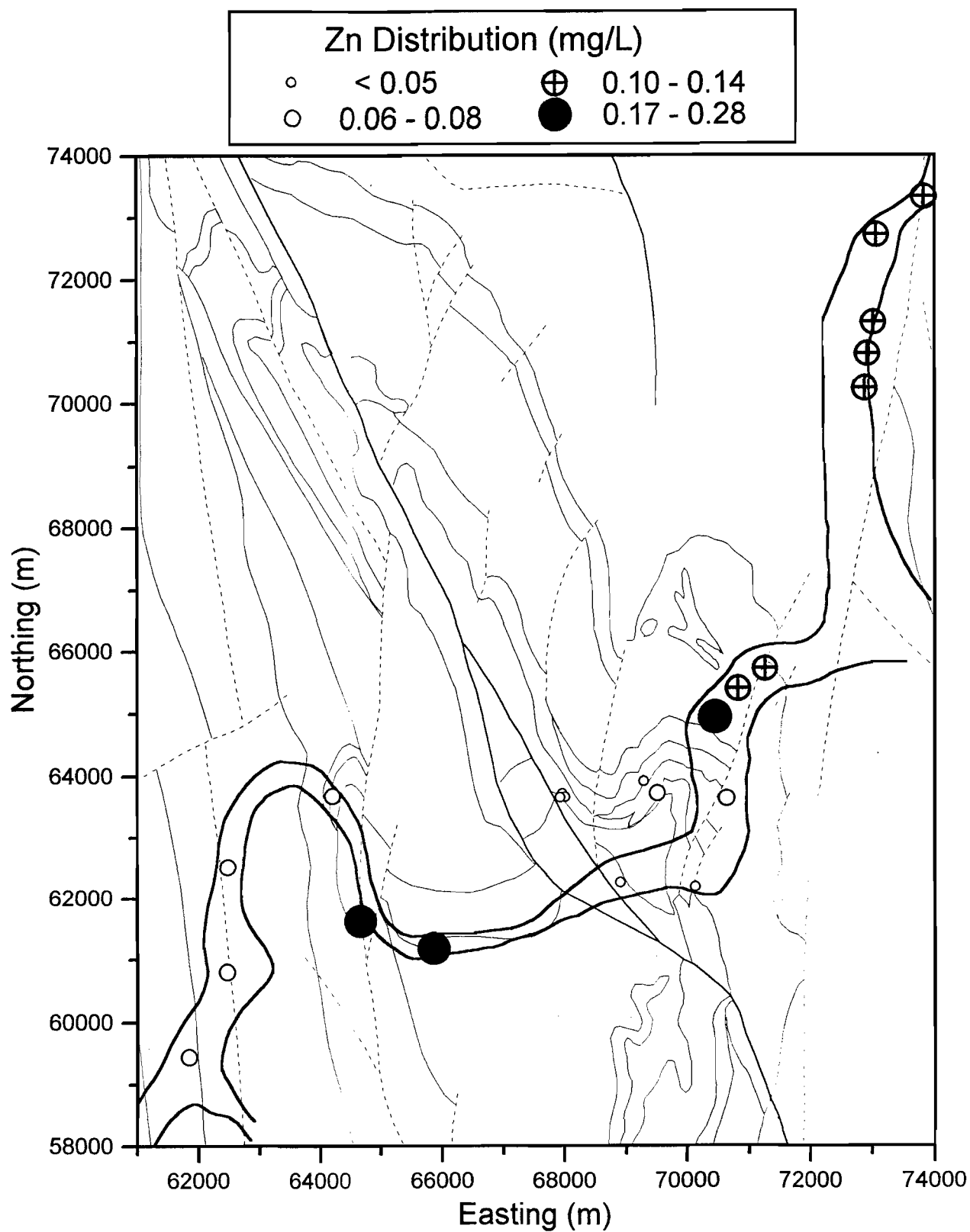


Figure A5.30: Zinc distribution in groundwater at Wollubar.

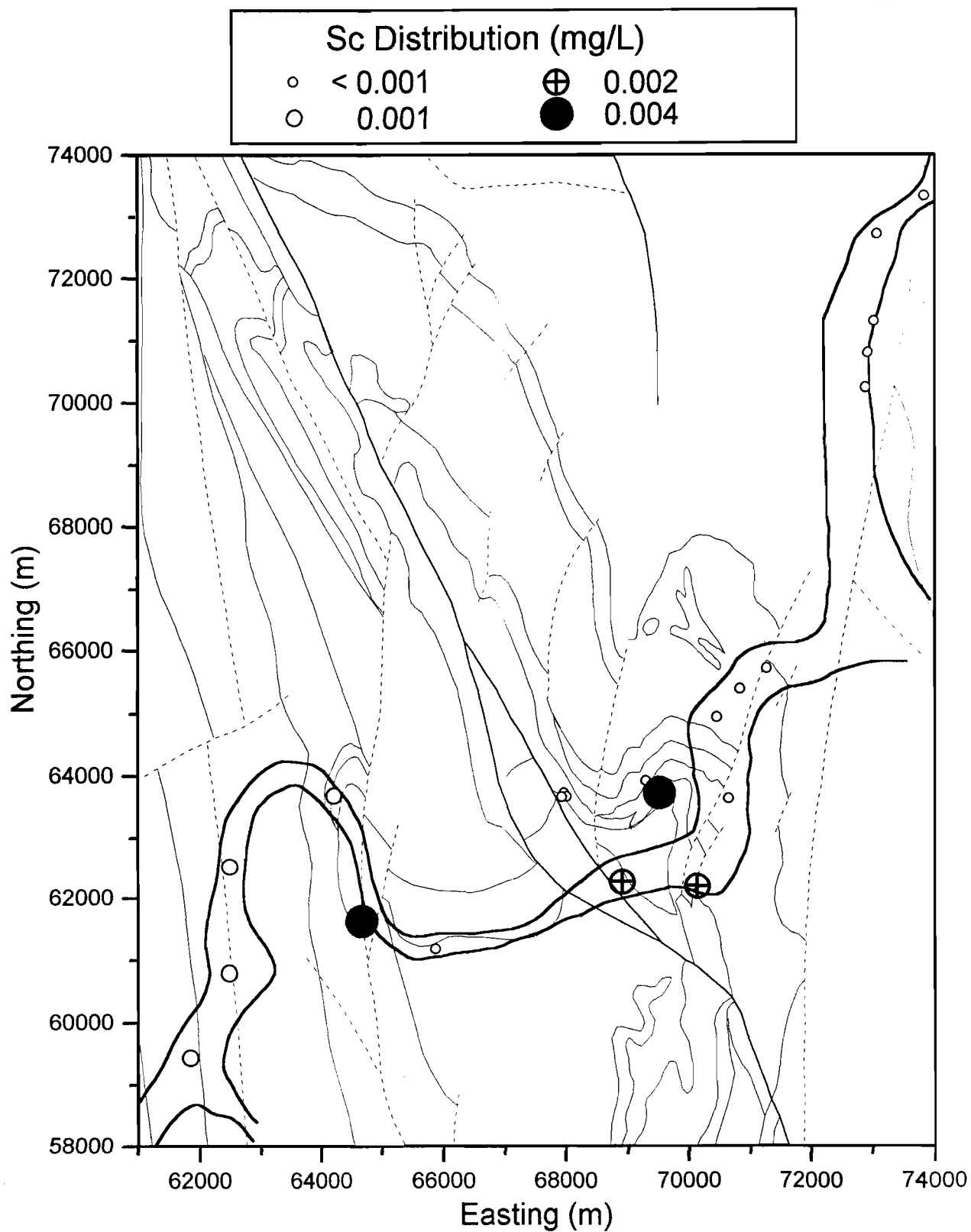


Figure A5.31: Scandium distribution in groundwater at Wollubar.

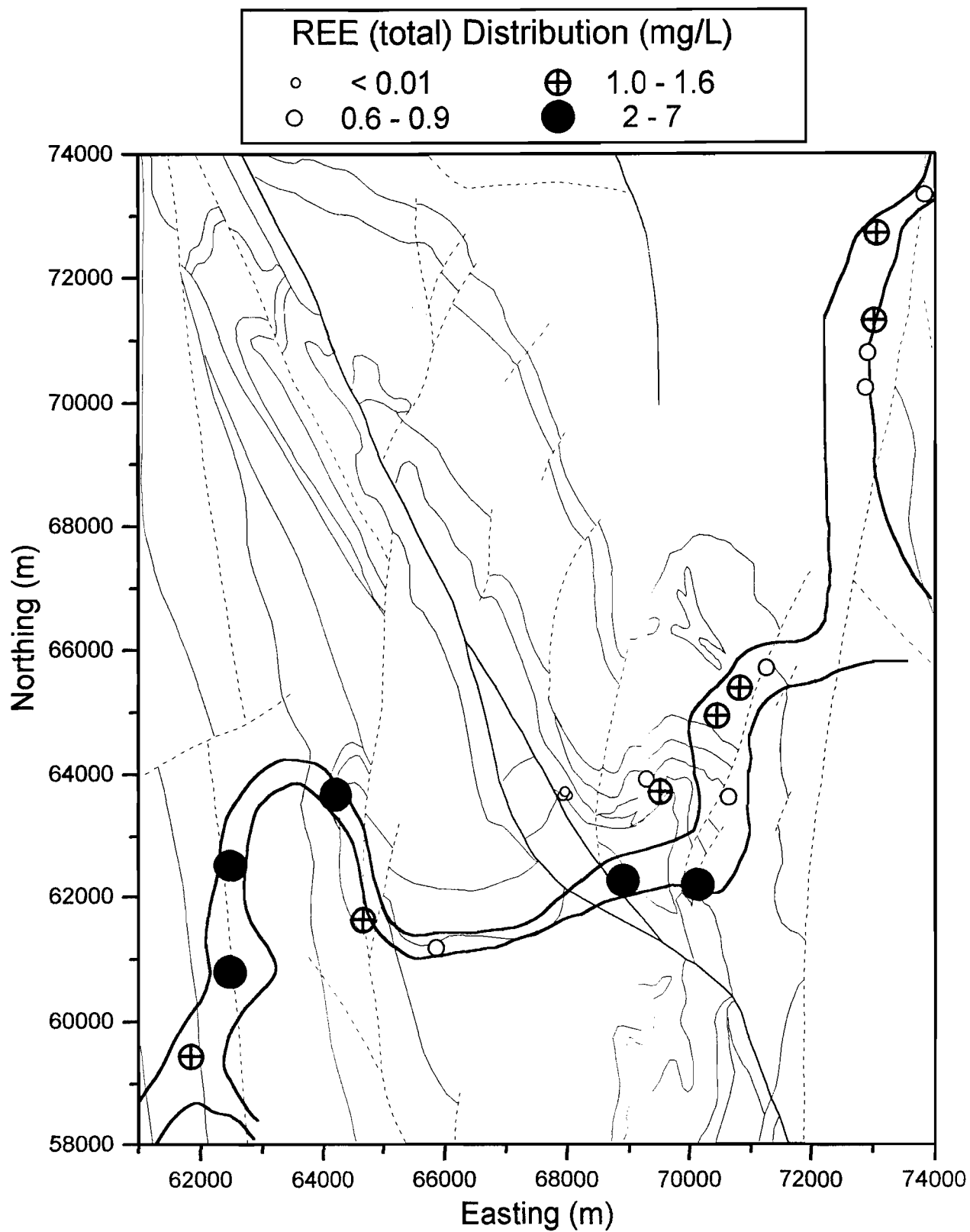


Figure A5.32: Total REE distribution in groundwater at Wollubar.

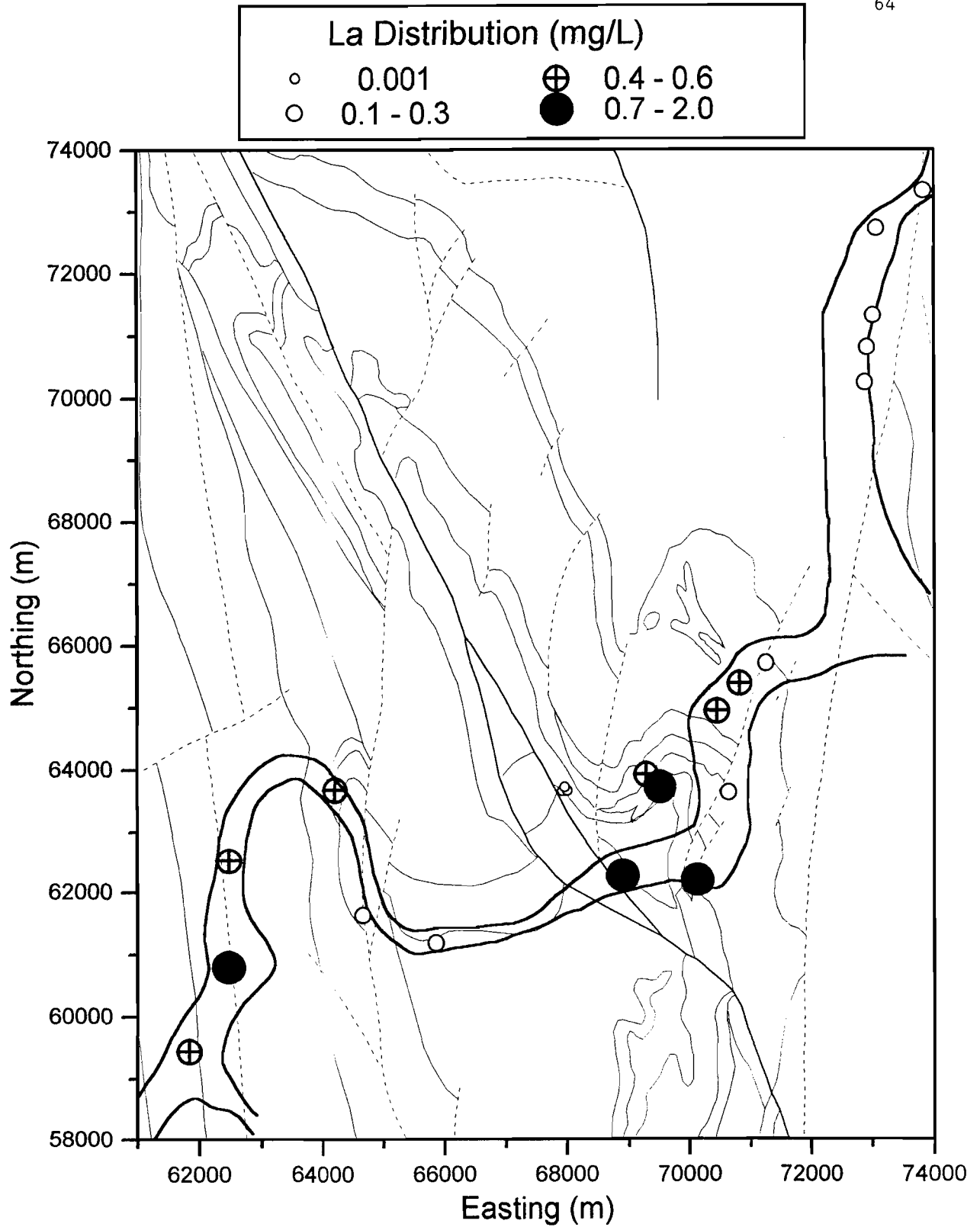


Figure A5.33: Lanthanum distribution in groundwater at Wollubar.

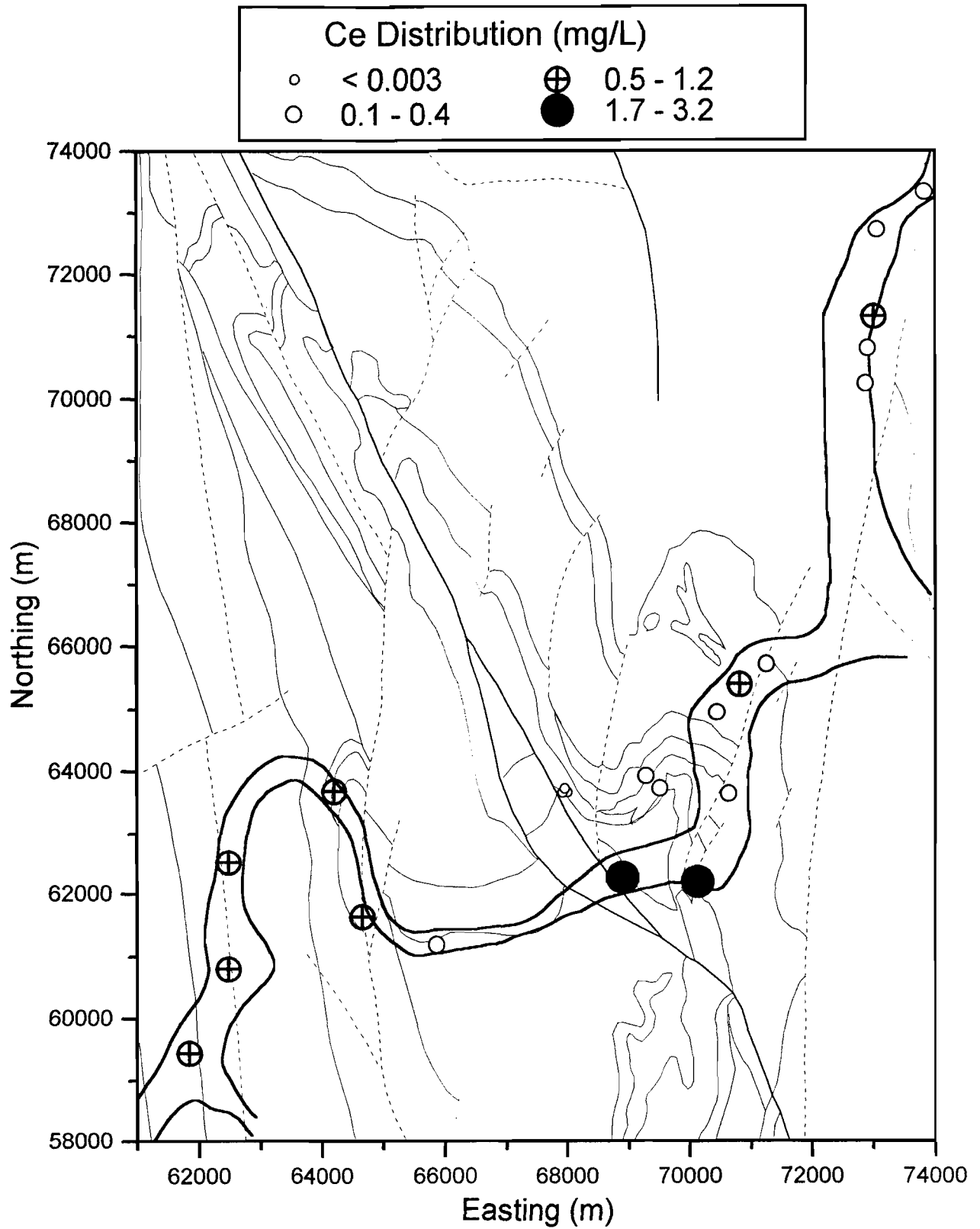


Figure A5.34: Cerium distribution in groundwater at Wollubar.

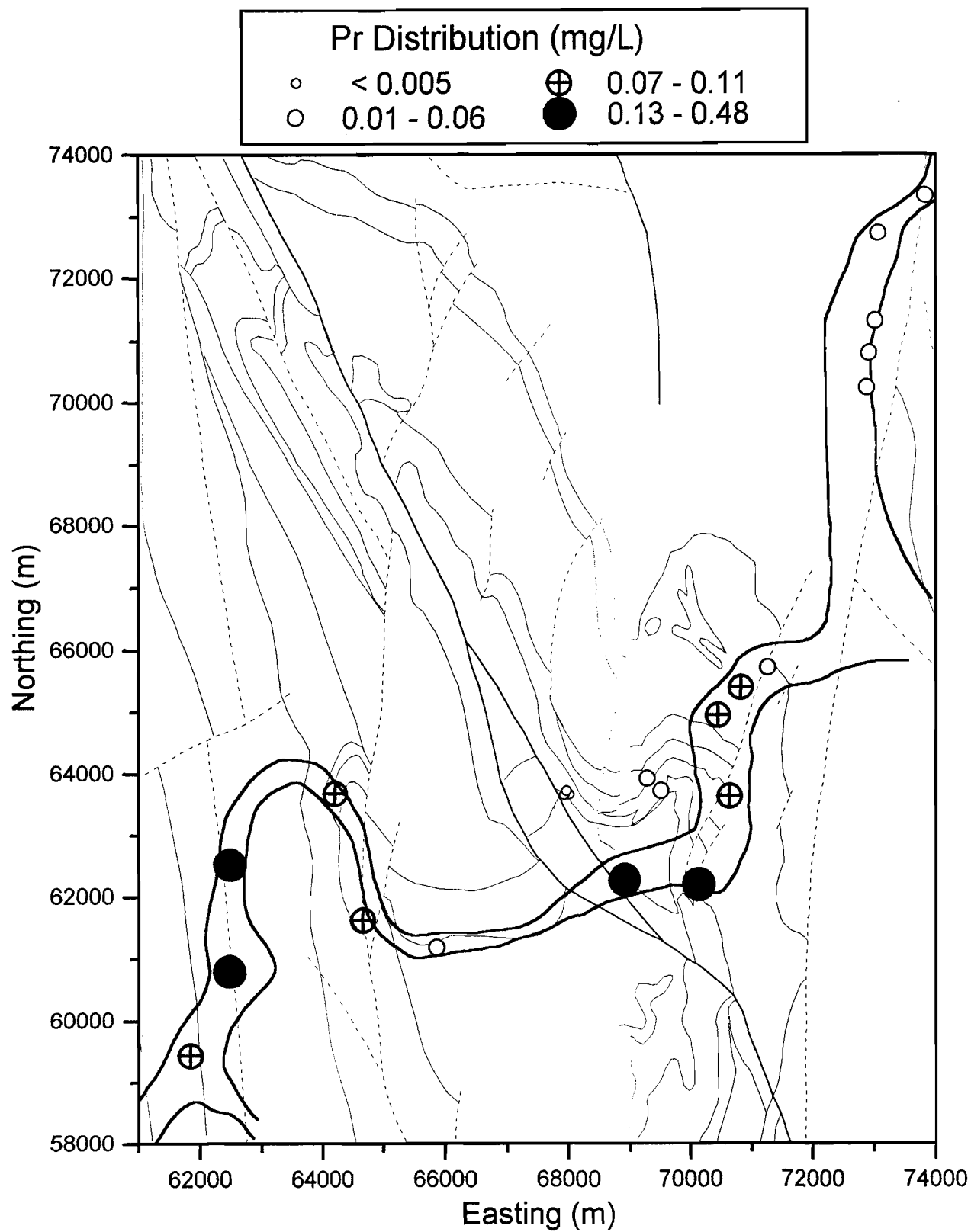


Figure A5.35: Praseodymium distribution in groundwater at Wollubar.

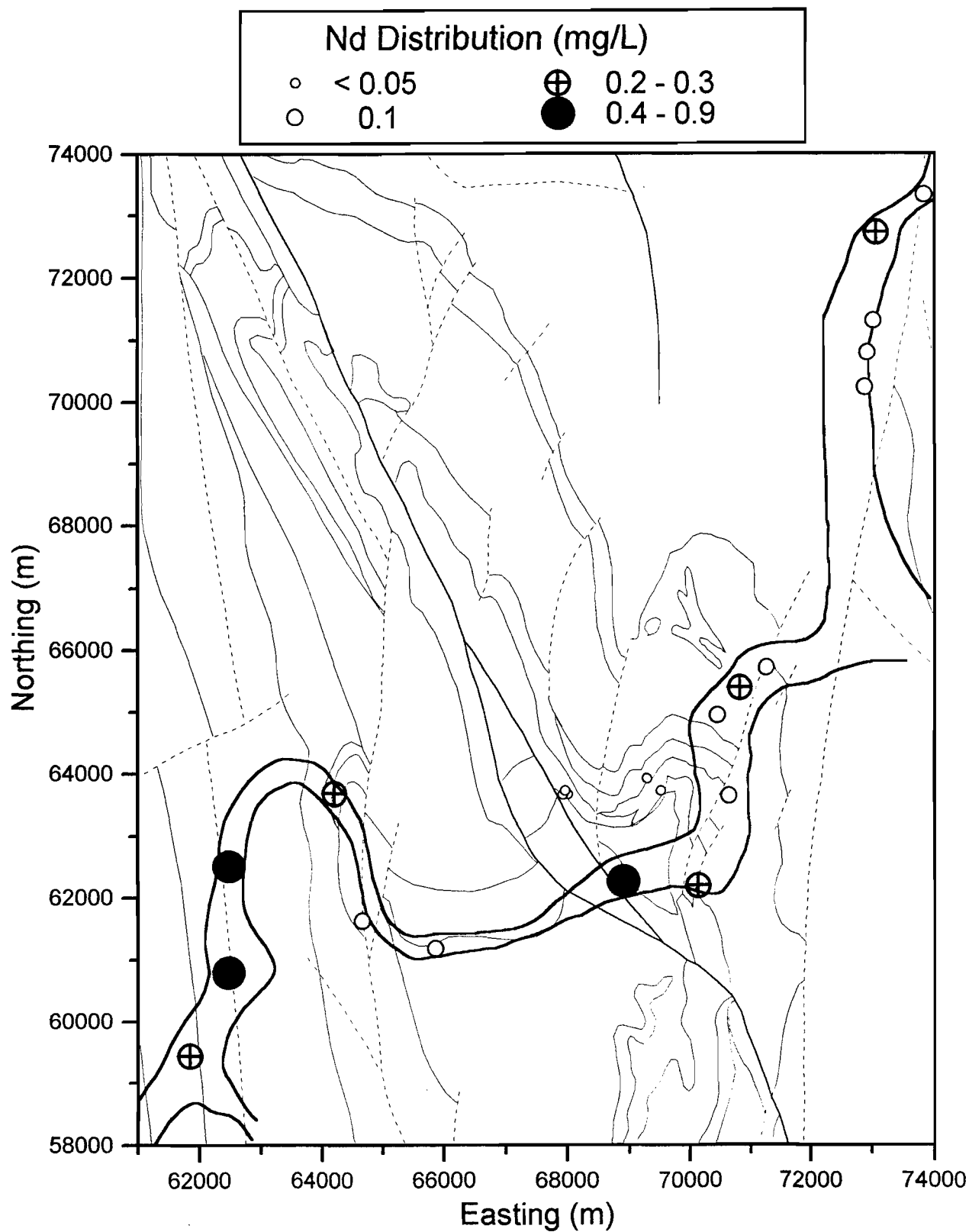


Figure A5.36: Neodymium distribution in groundwater at Wollubar.

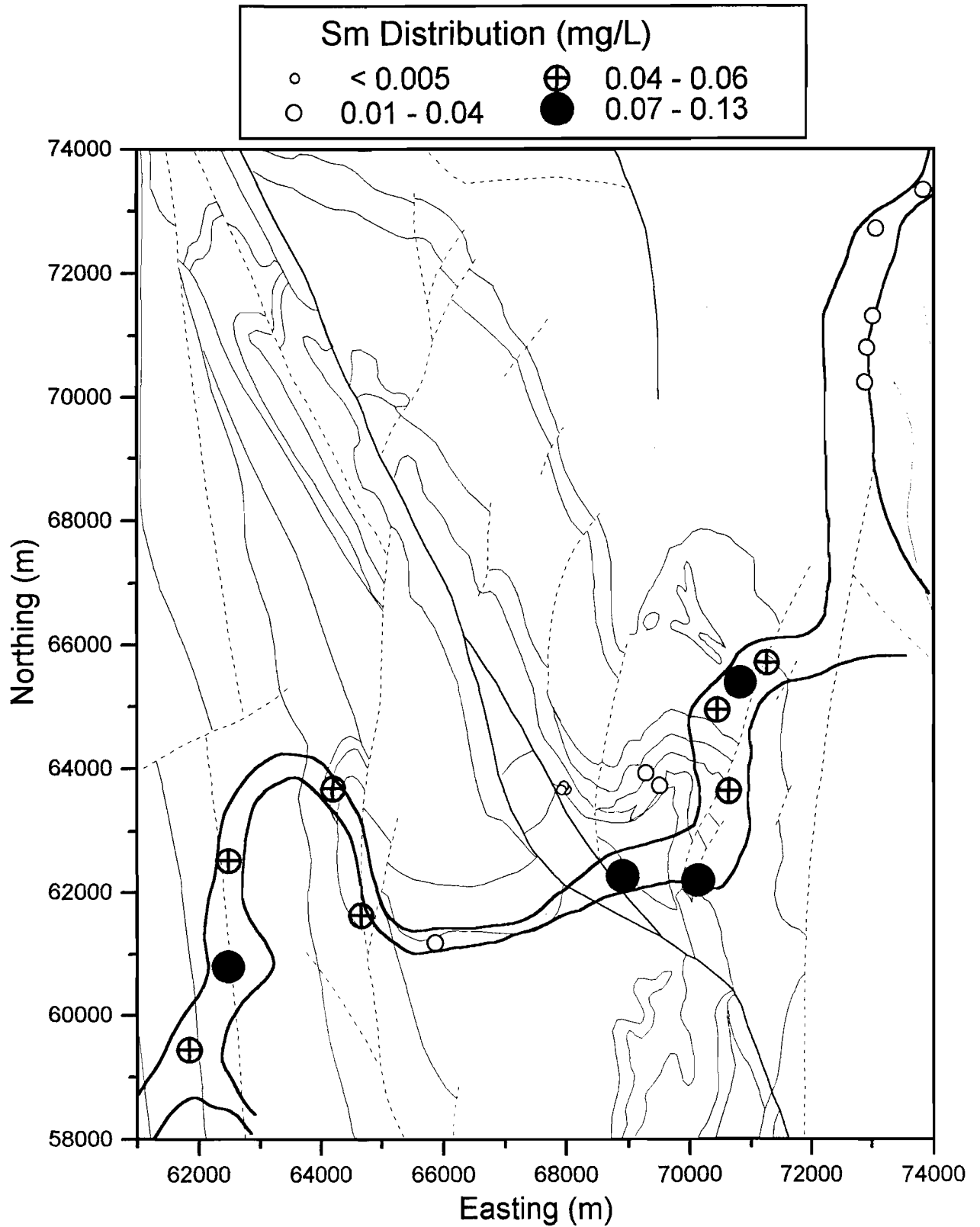


Figure A5.37: Samarium distribution in groundwater at Wollubar.

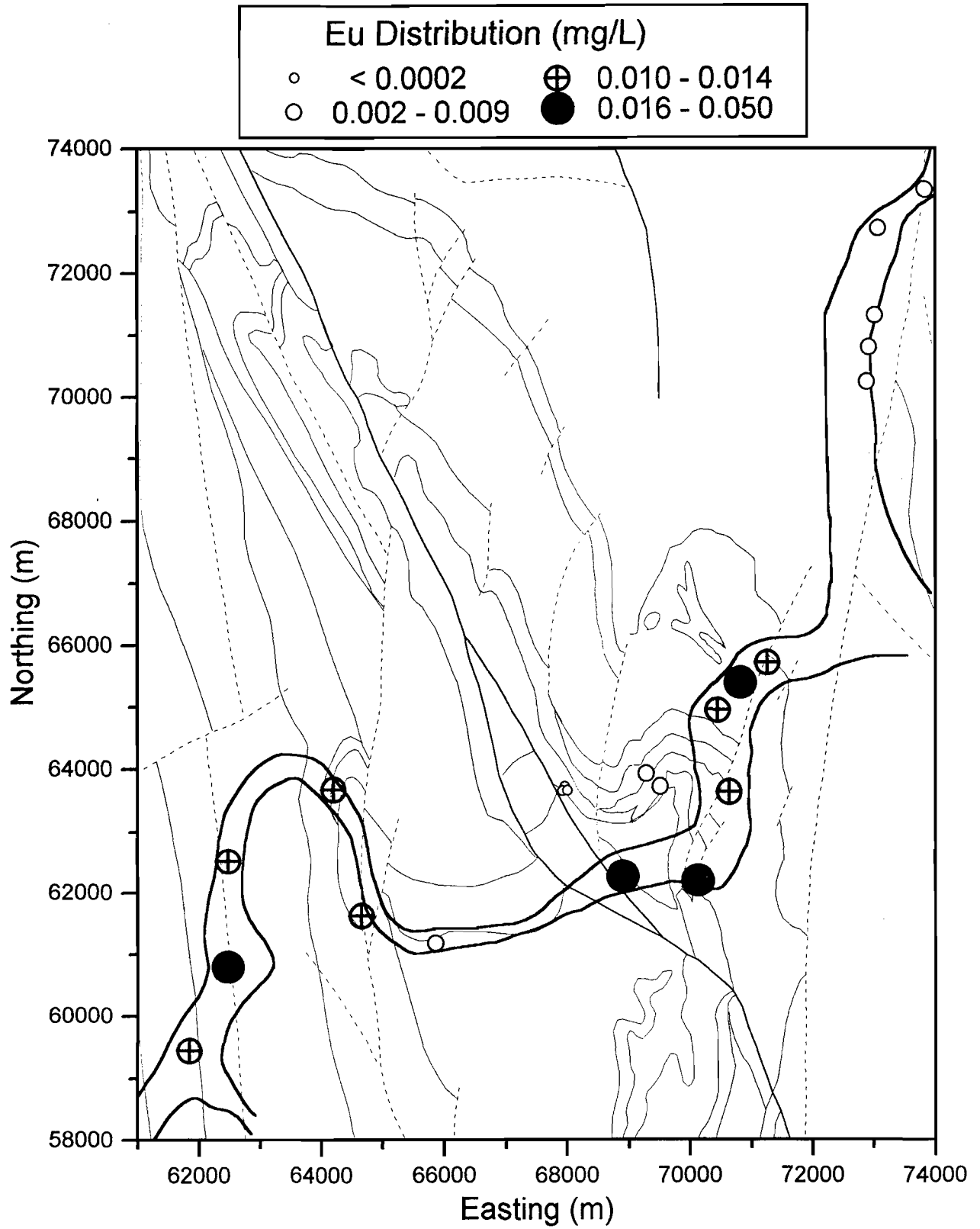


Figure A5.38: Europium distribution in groundwater at Wollubar.

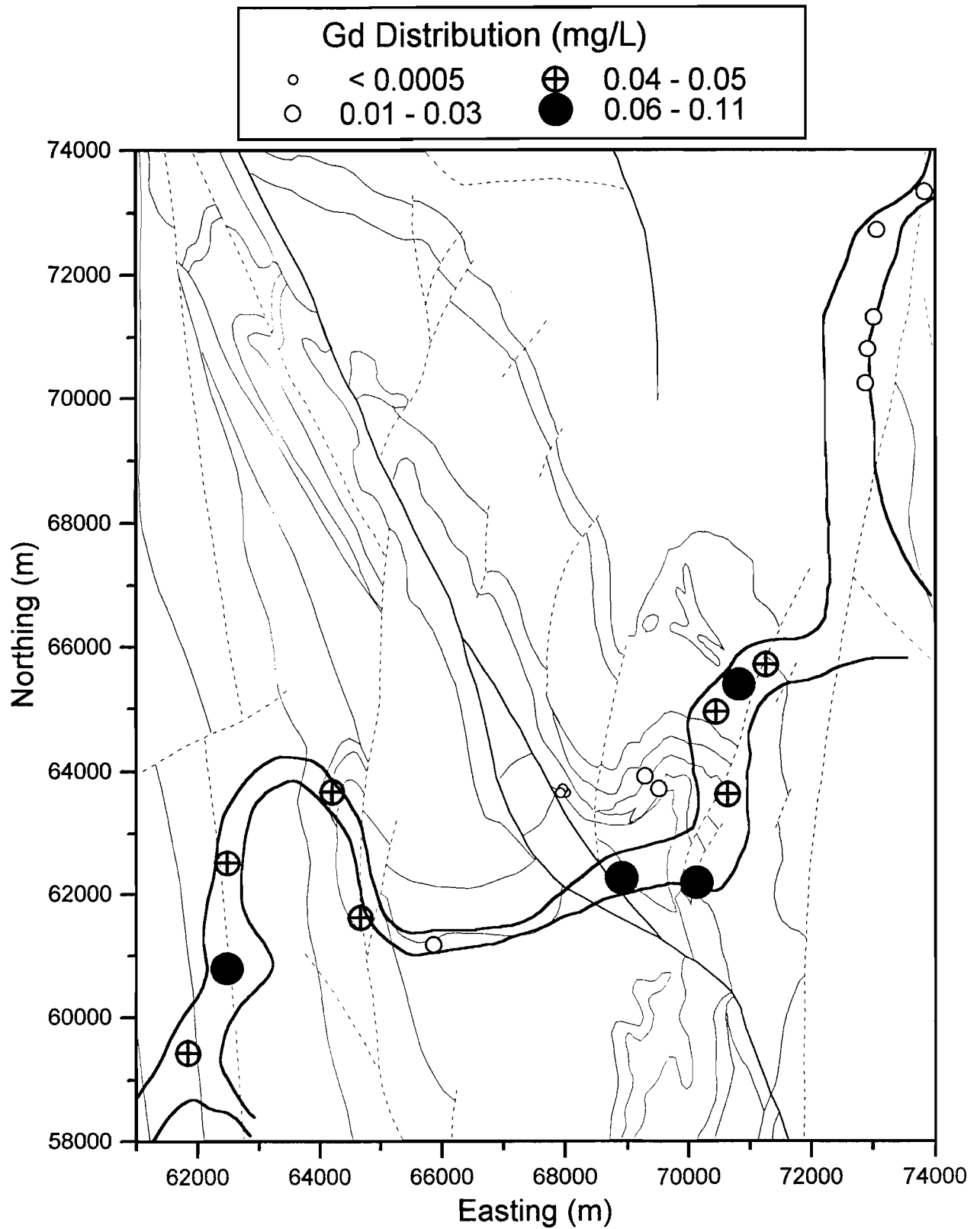


Figure A5.39: Gadolinium distribution in groundwater at Wollubar.

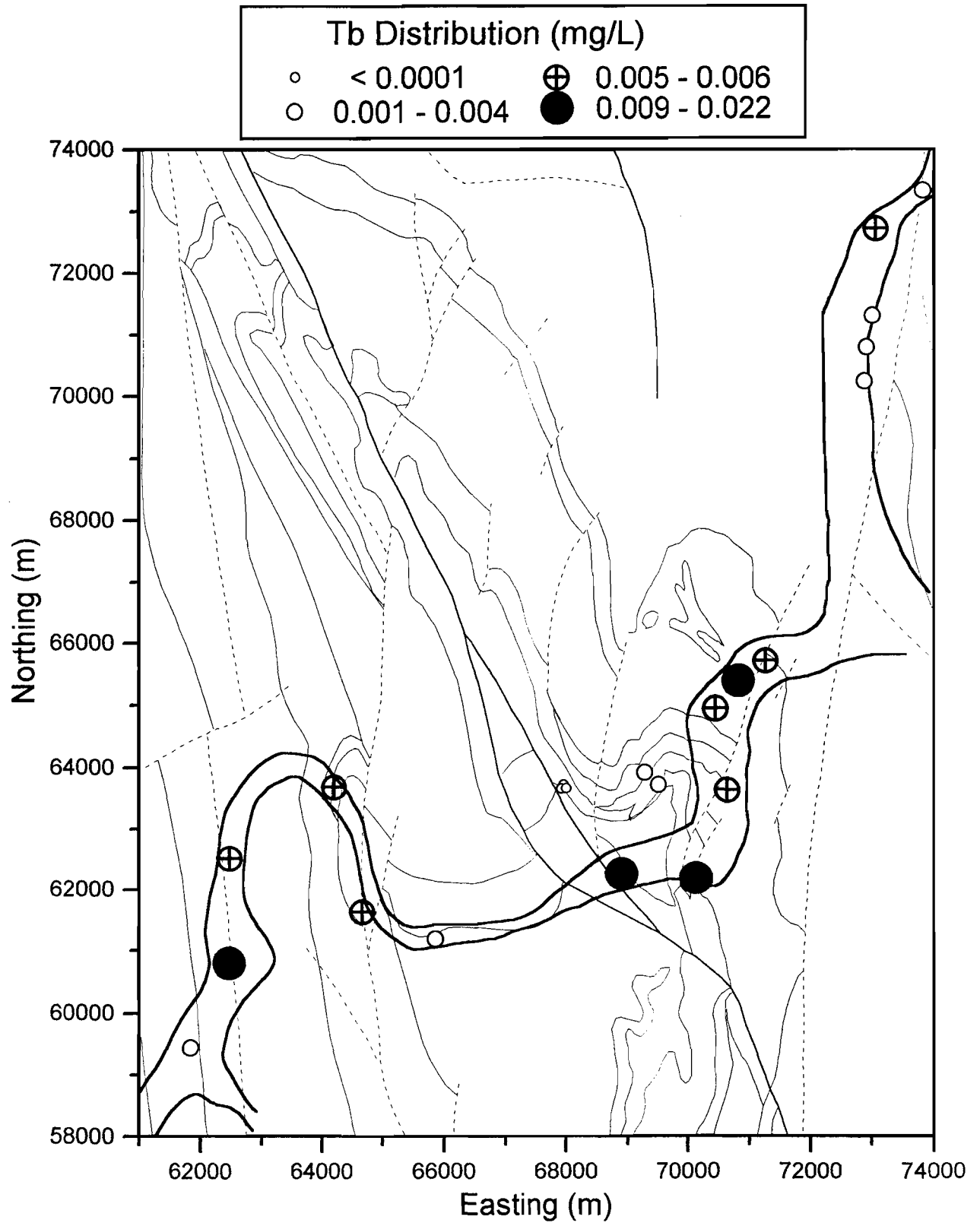


Figure A5.40: Terbium distribution in groundwater at Wollubar.

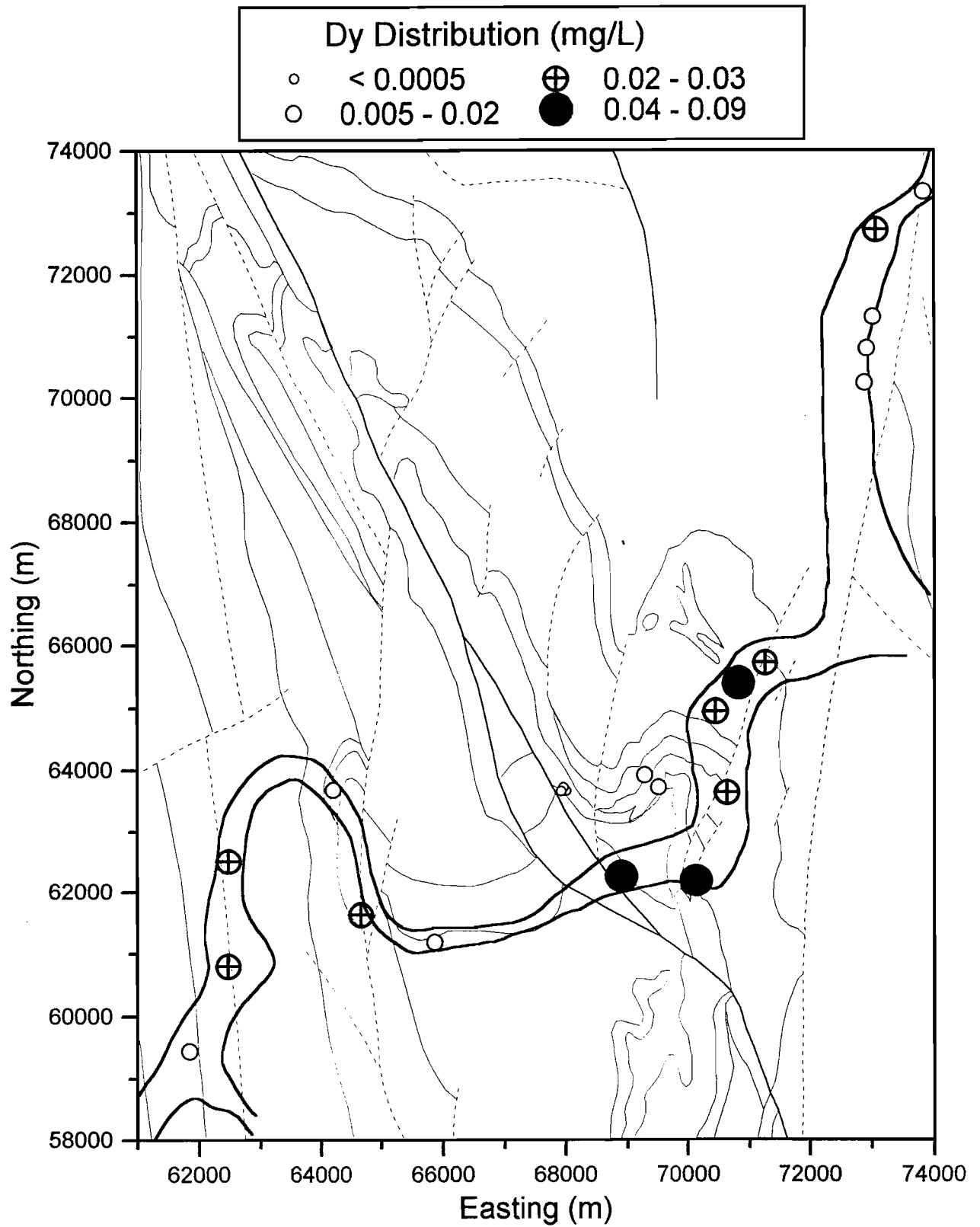


Figure A5.41: Dysprosium distribution in groundwater at Wollubar.

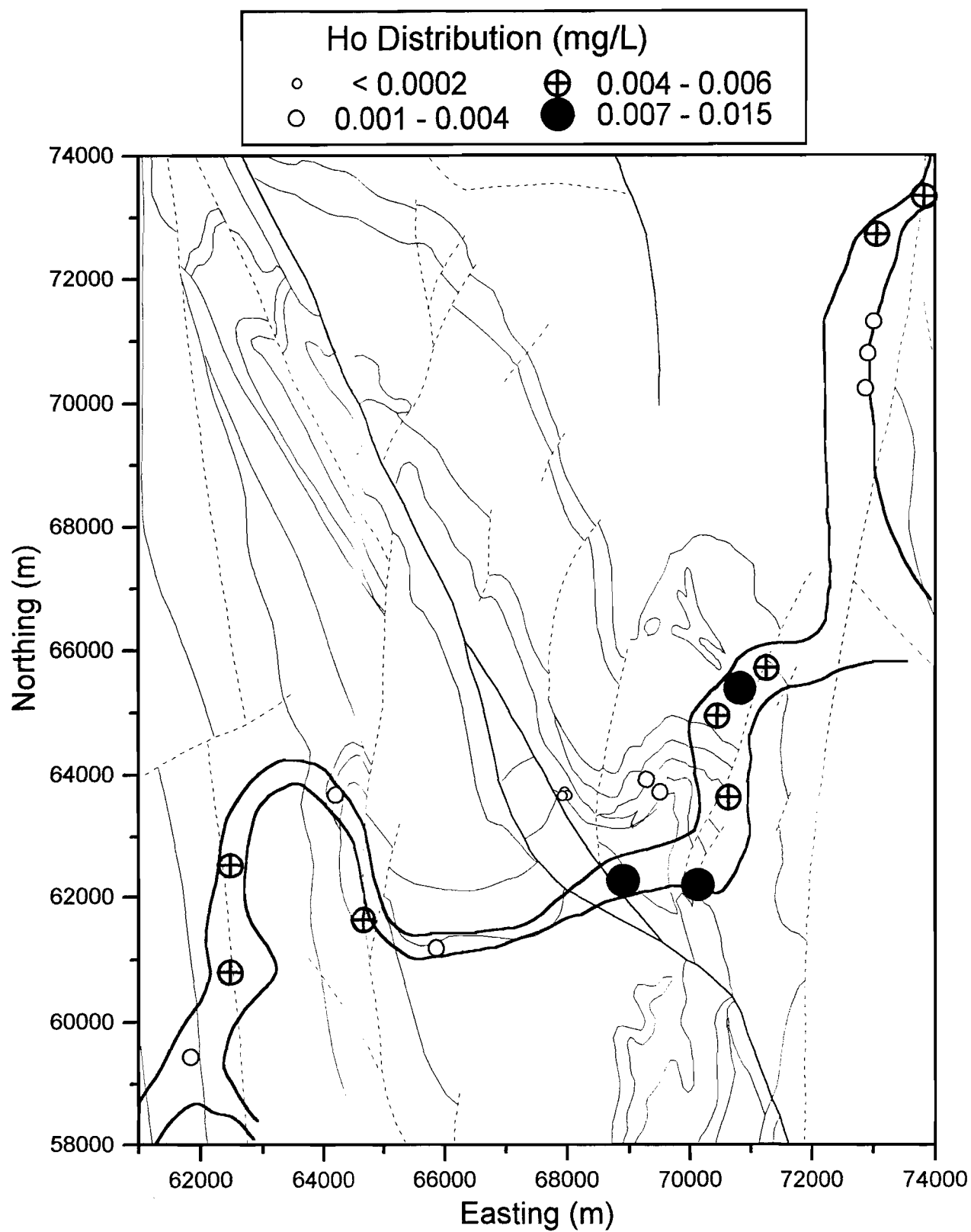


Figure A5.42: Holmium distribution in groundwater at Wollubar.

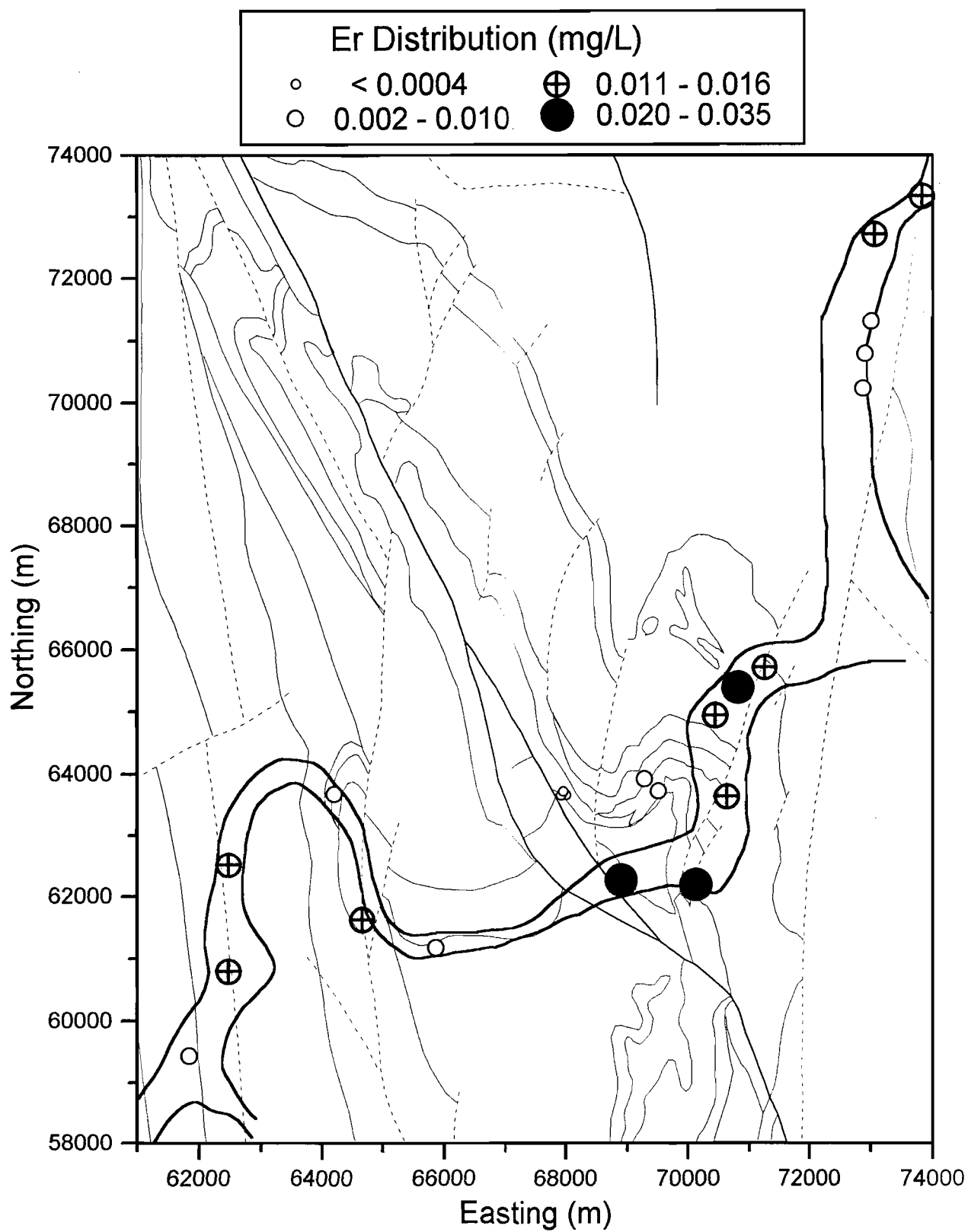


Figure A5.43: Erbium distribution in groundwater at Wollubar.

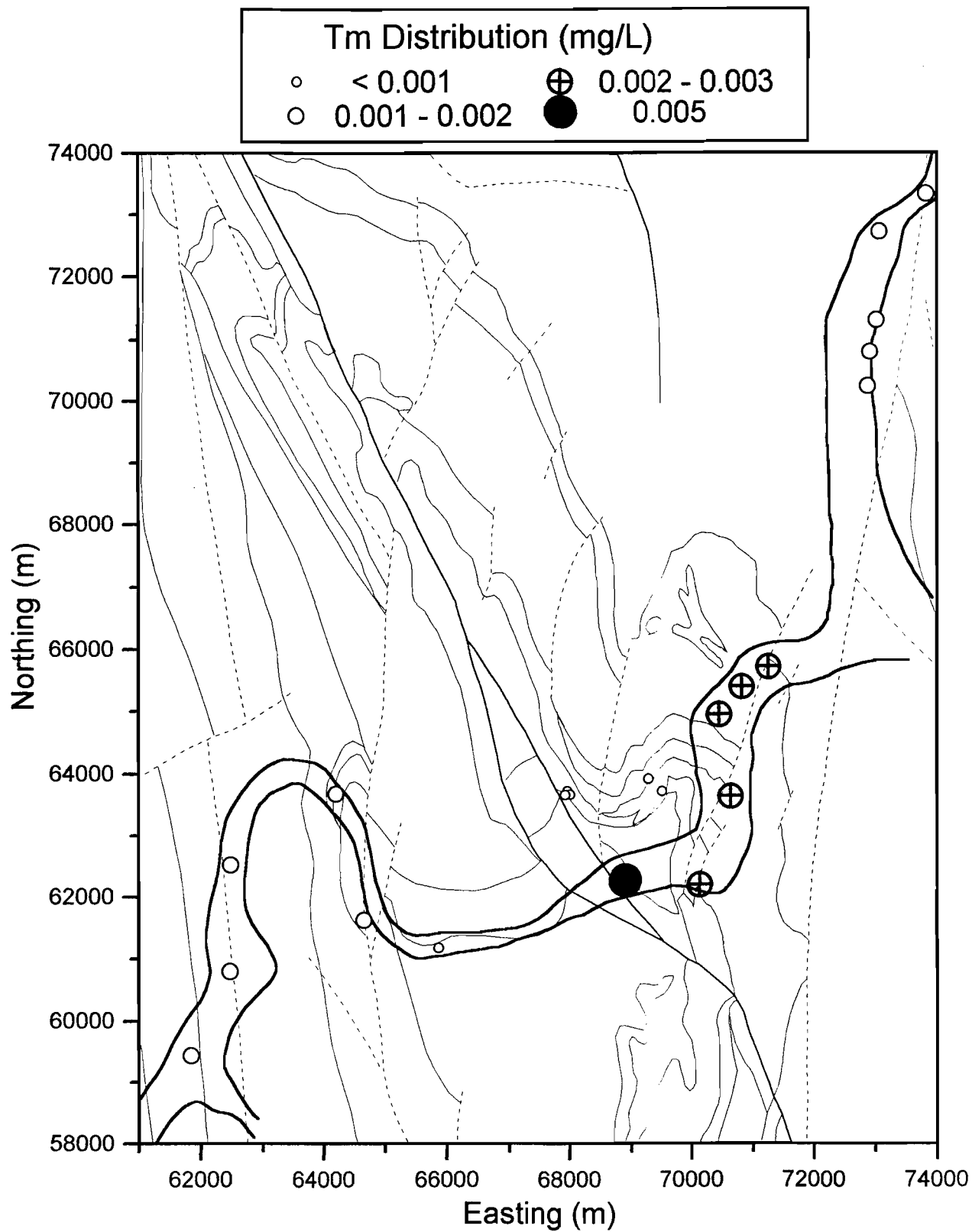


Figure A5.44: Thulium distribution in groundwater at Wollubar.

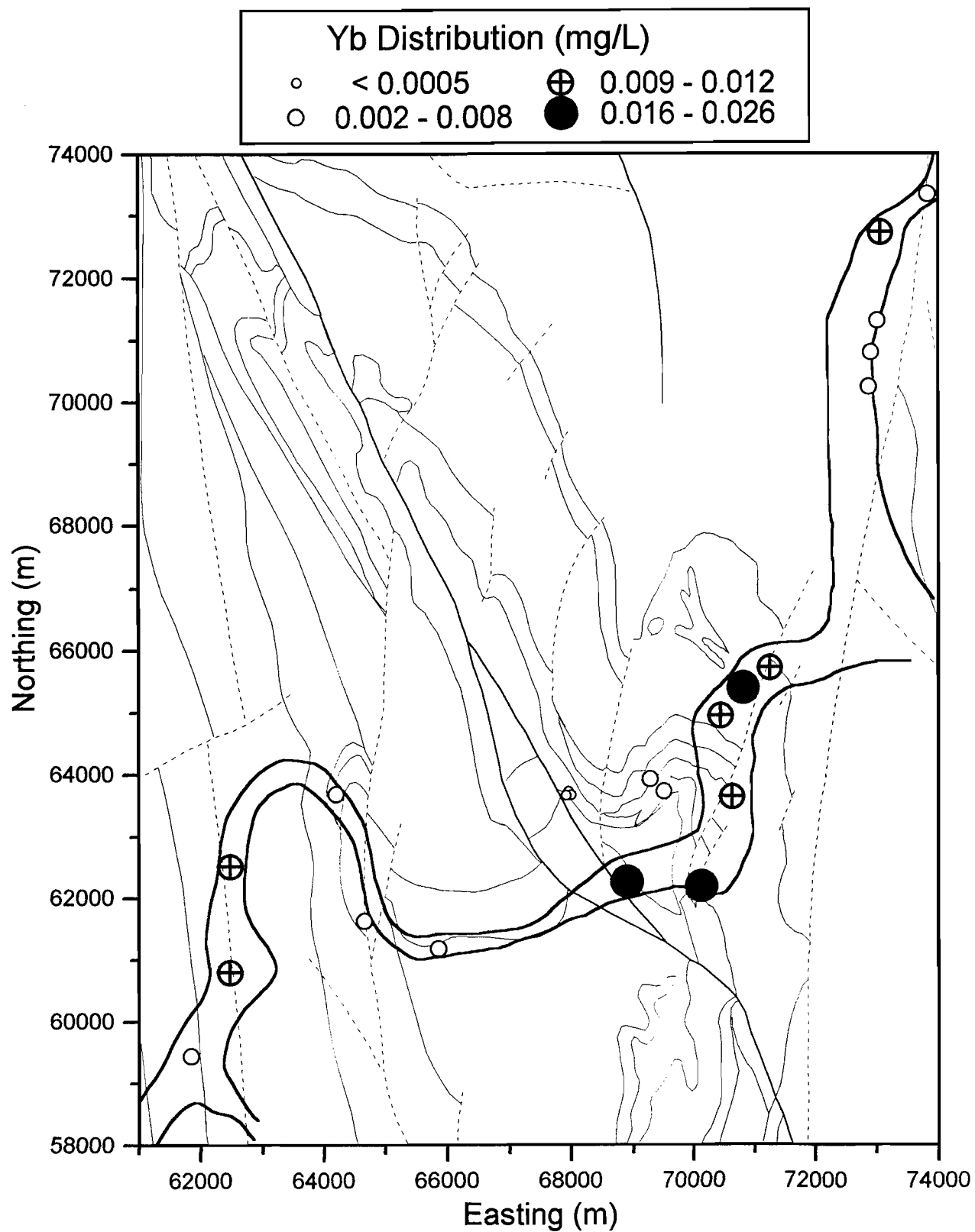


Figure A5.45: Ytterbium distribution in groundwater at Wollubar.

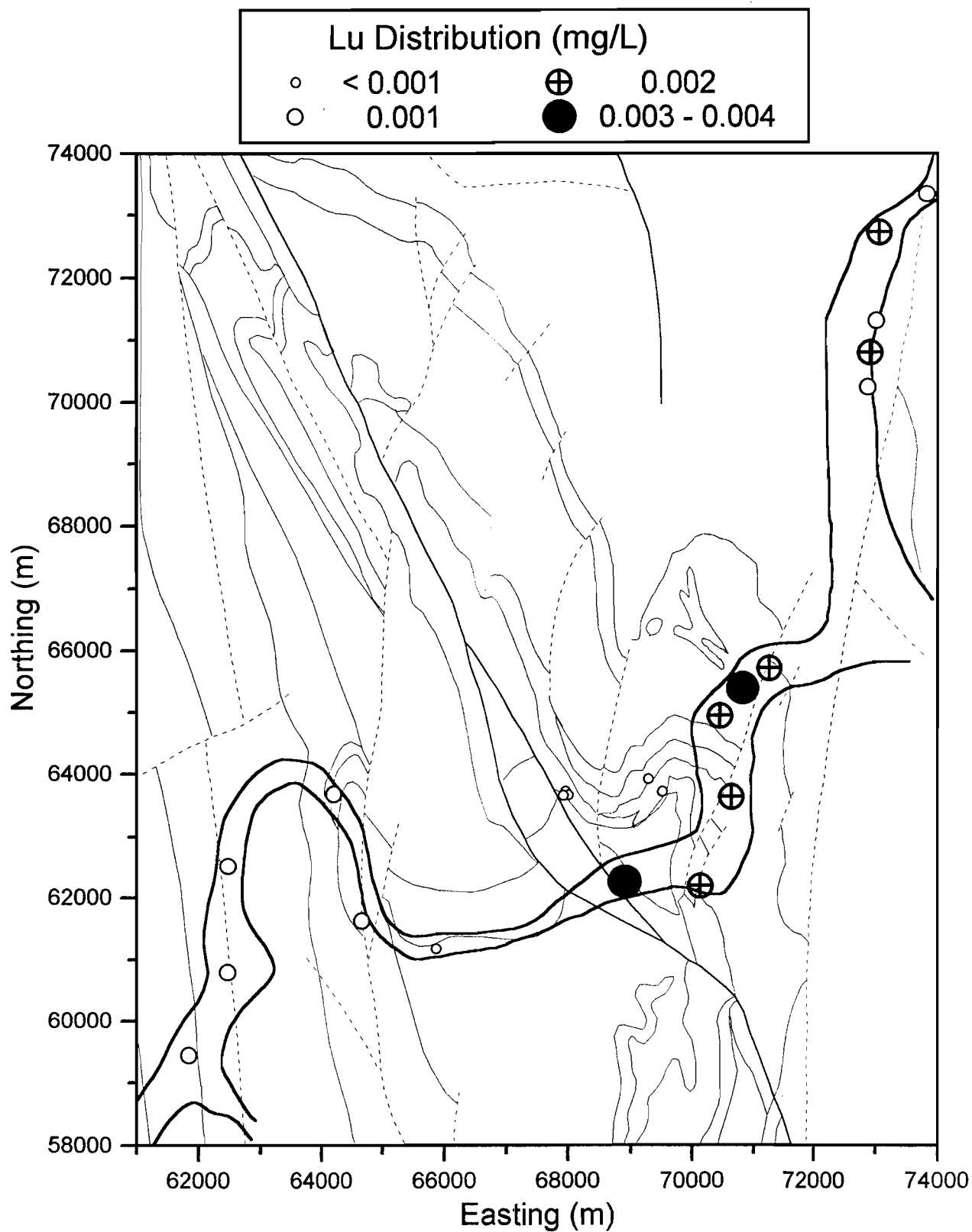


Figure A5.46: Lutetium distribution in groundwater at Wollubar.

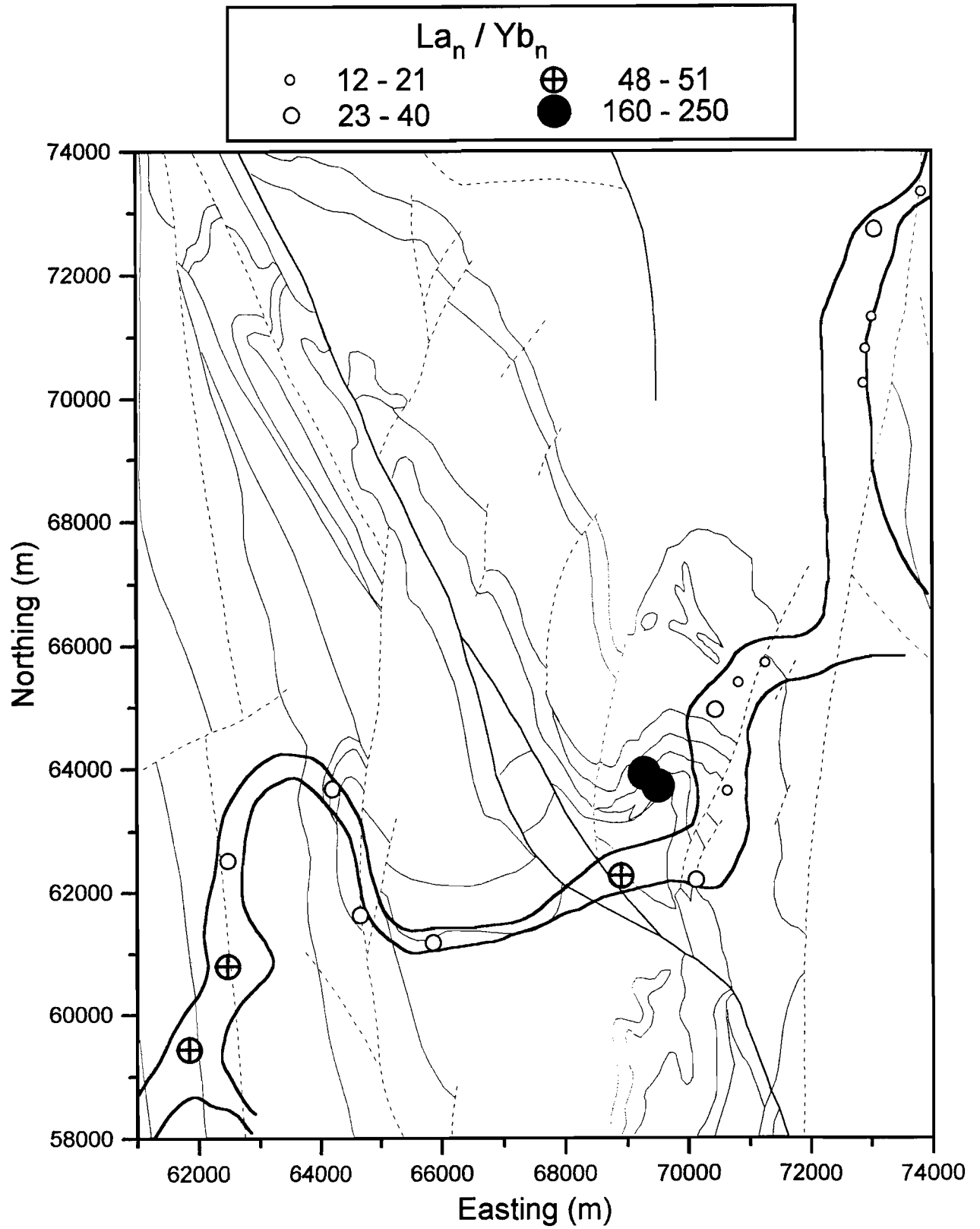


Figure A5.47: La_n / Yb_n distribution in groundwater at Wollubar.

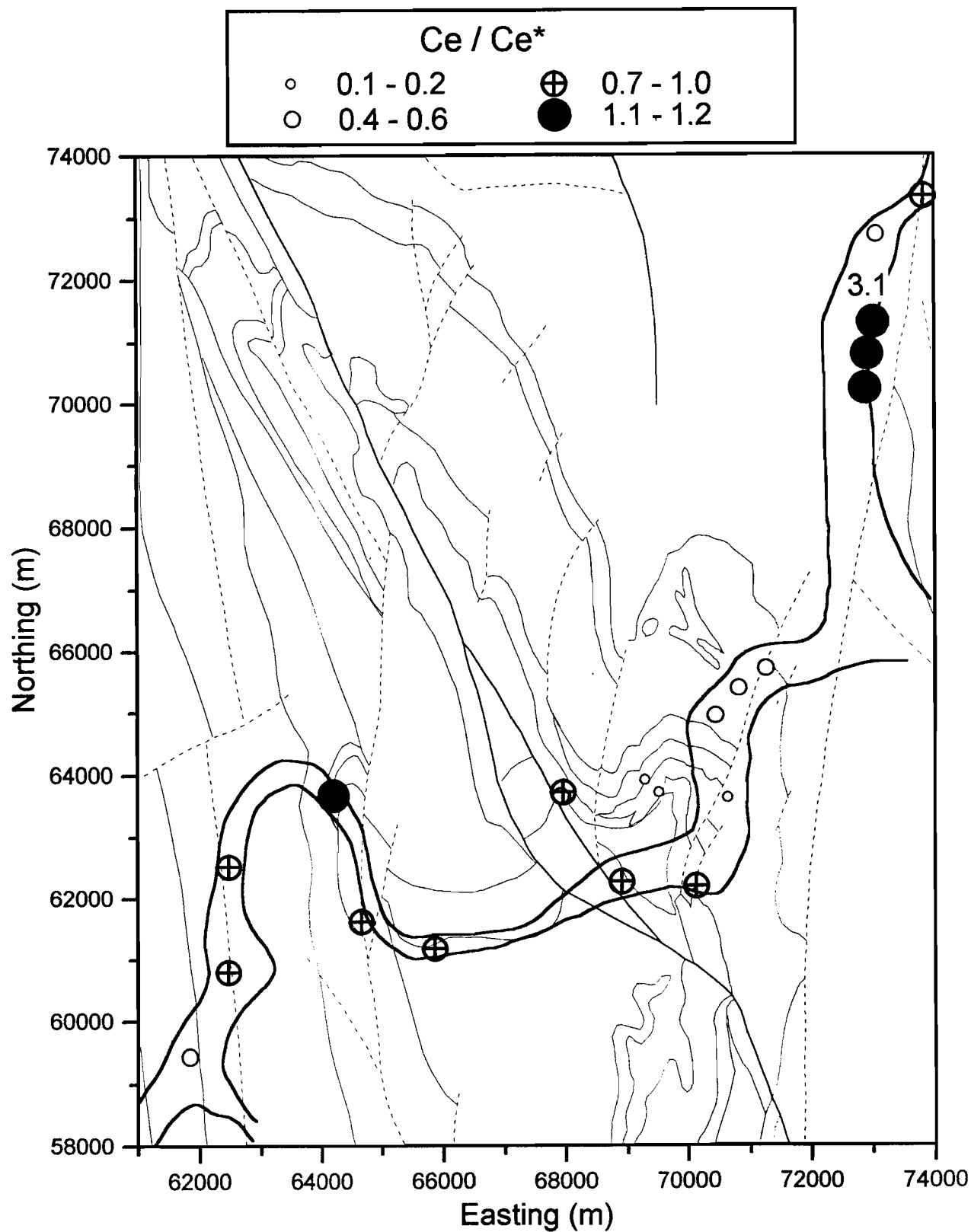


Figure A5.48: Ce/Ce* distribution in groundwater at Wollubar.

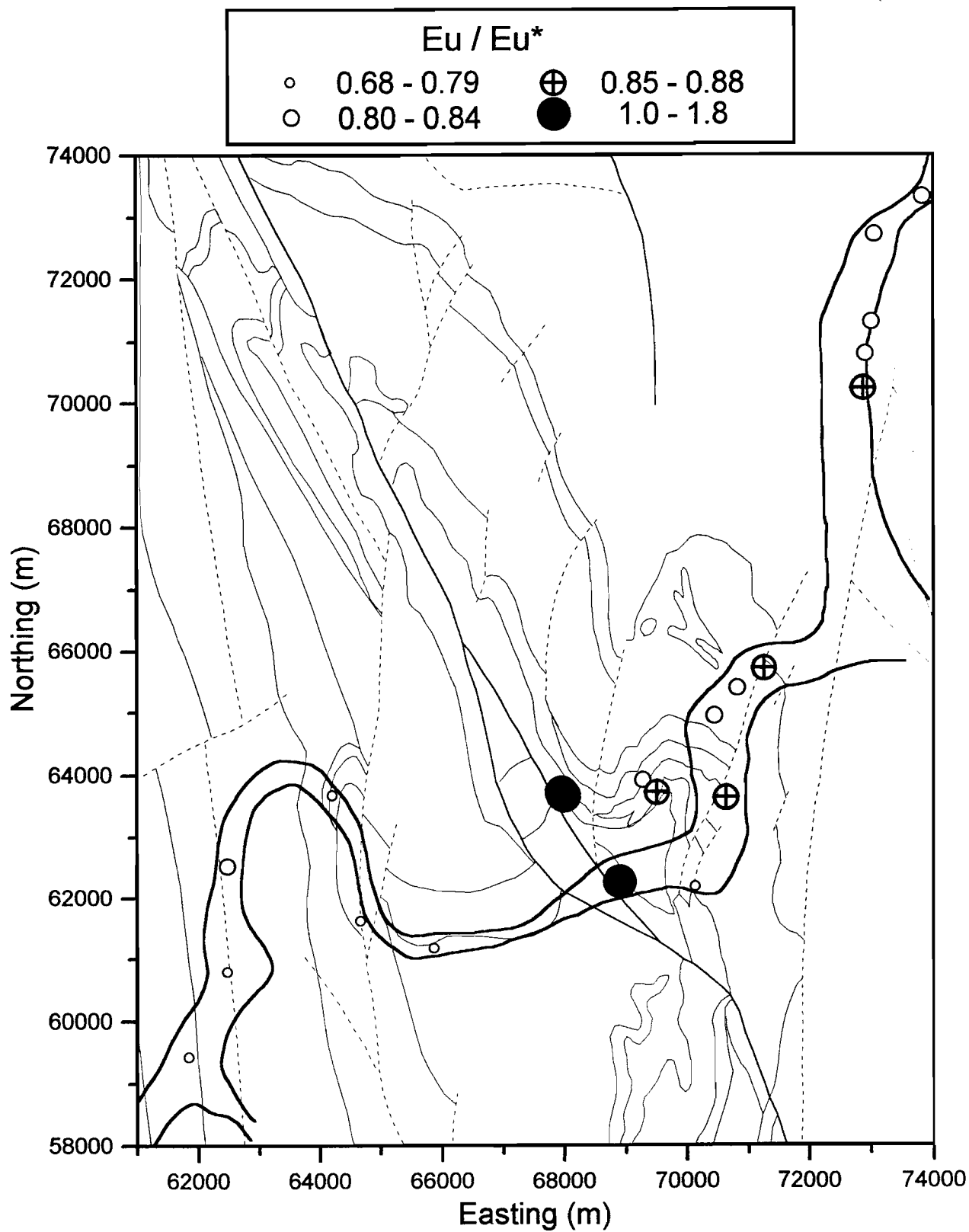


Figure A5.49: Eu/Eu* distribution in groundwater at Wollubar.

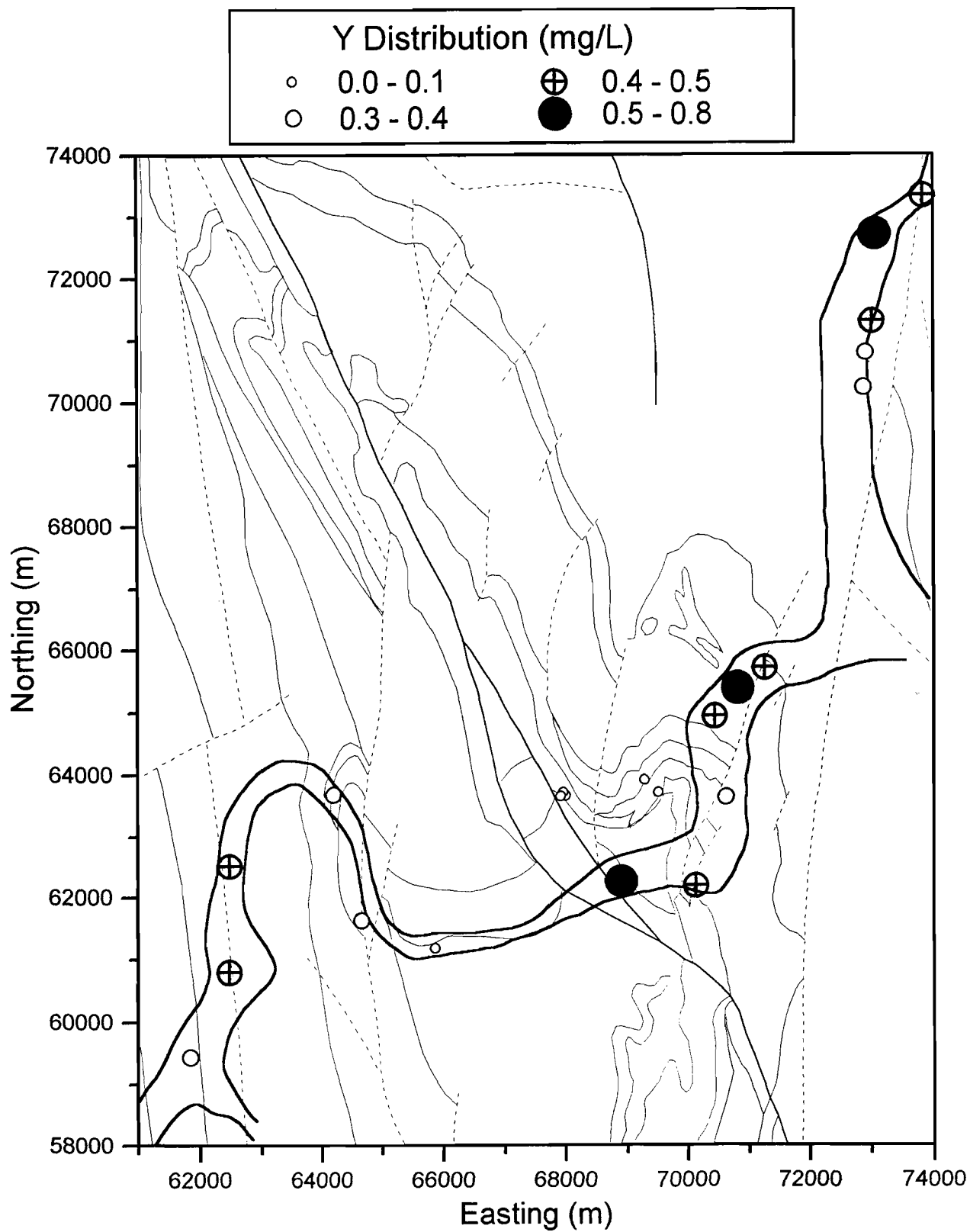


Figure A5.50: Yttrium distribution in groundwater at Wollubar.

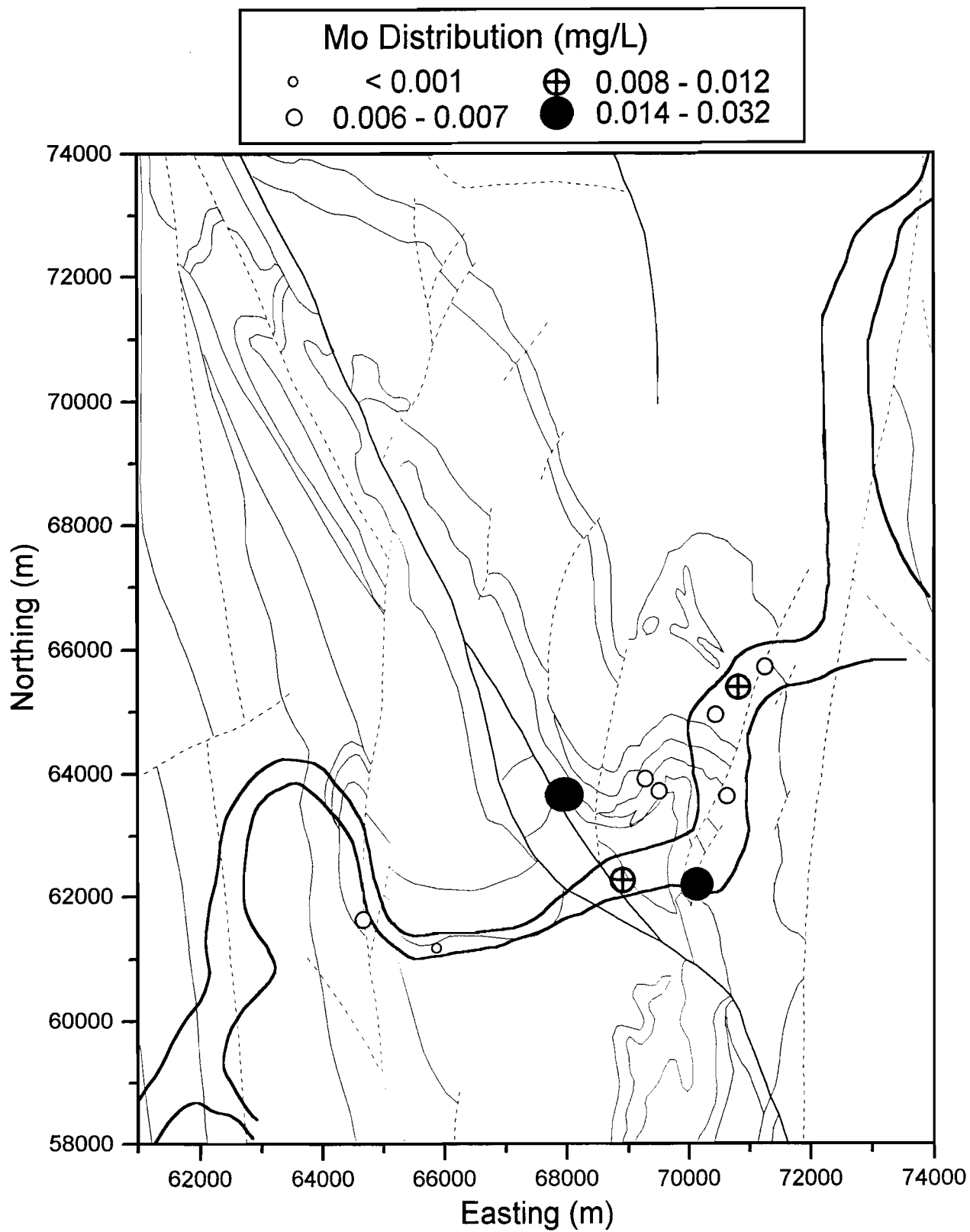


Figure A5.51: Molybdenum distribution in groundwater at Wollubar.

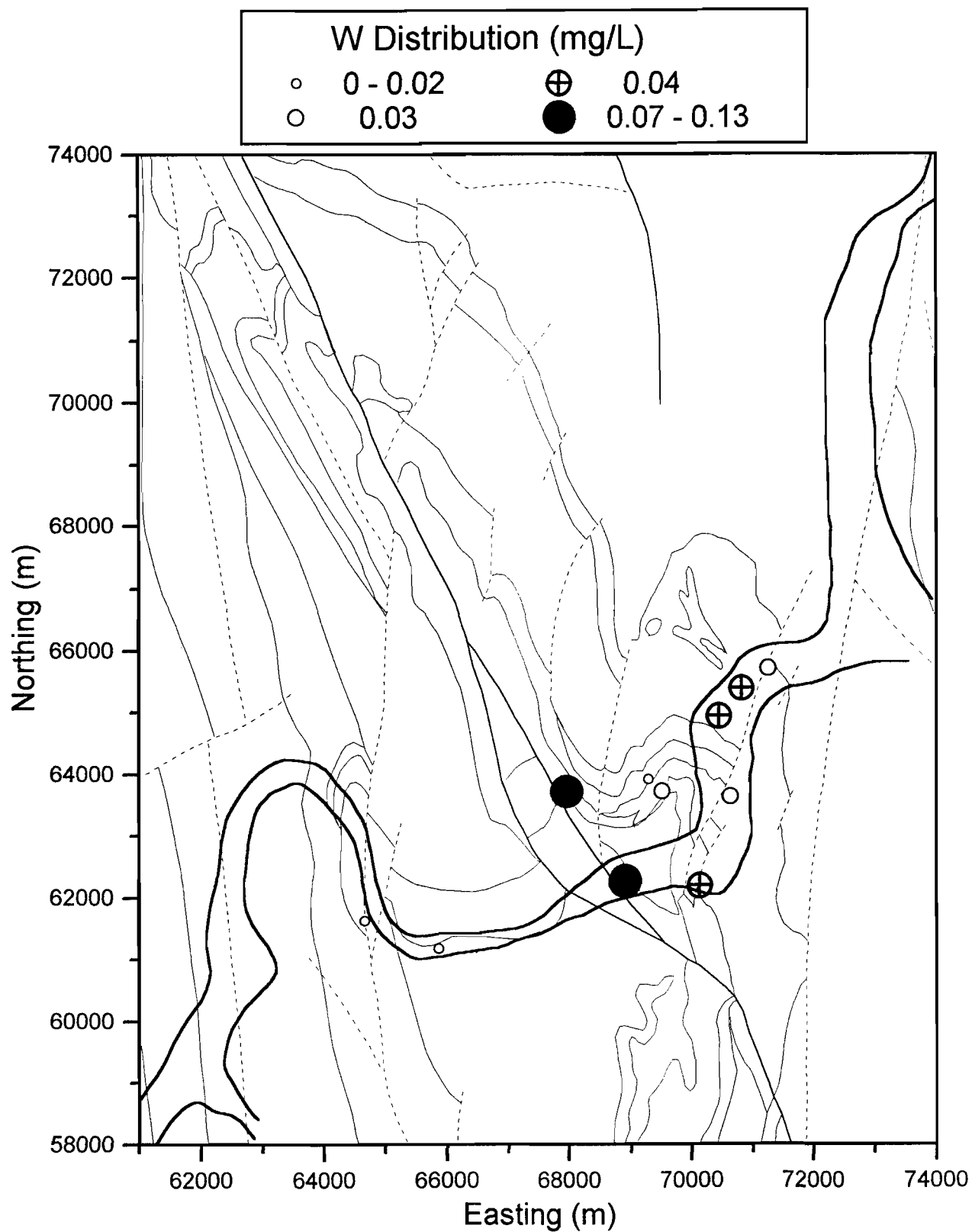


Figure A5.52: Tungsten distribution in groundwater at Wollubar.

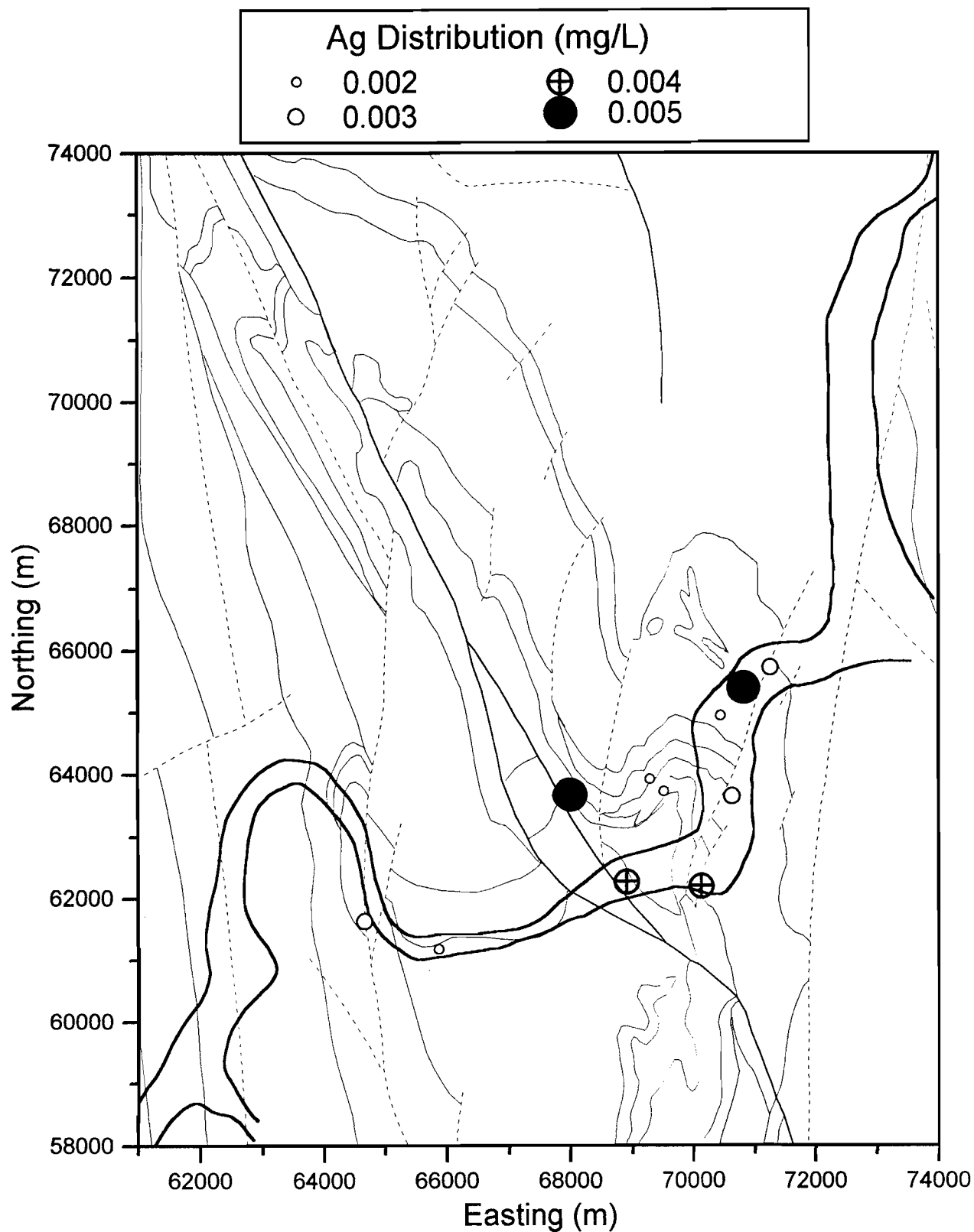


Figure A5.53: Silver distribution in groundwater at Wollubar.

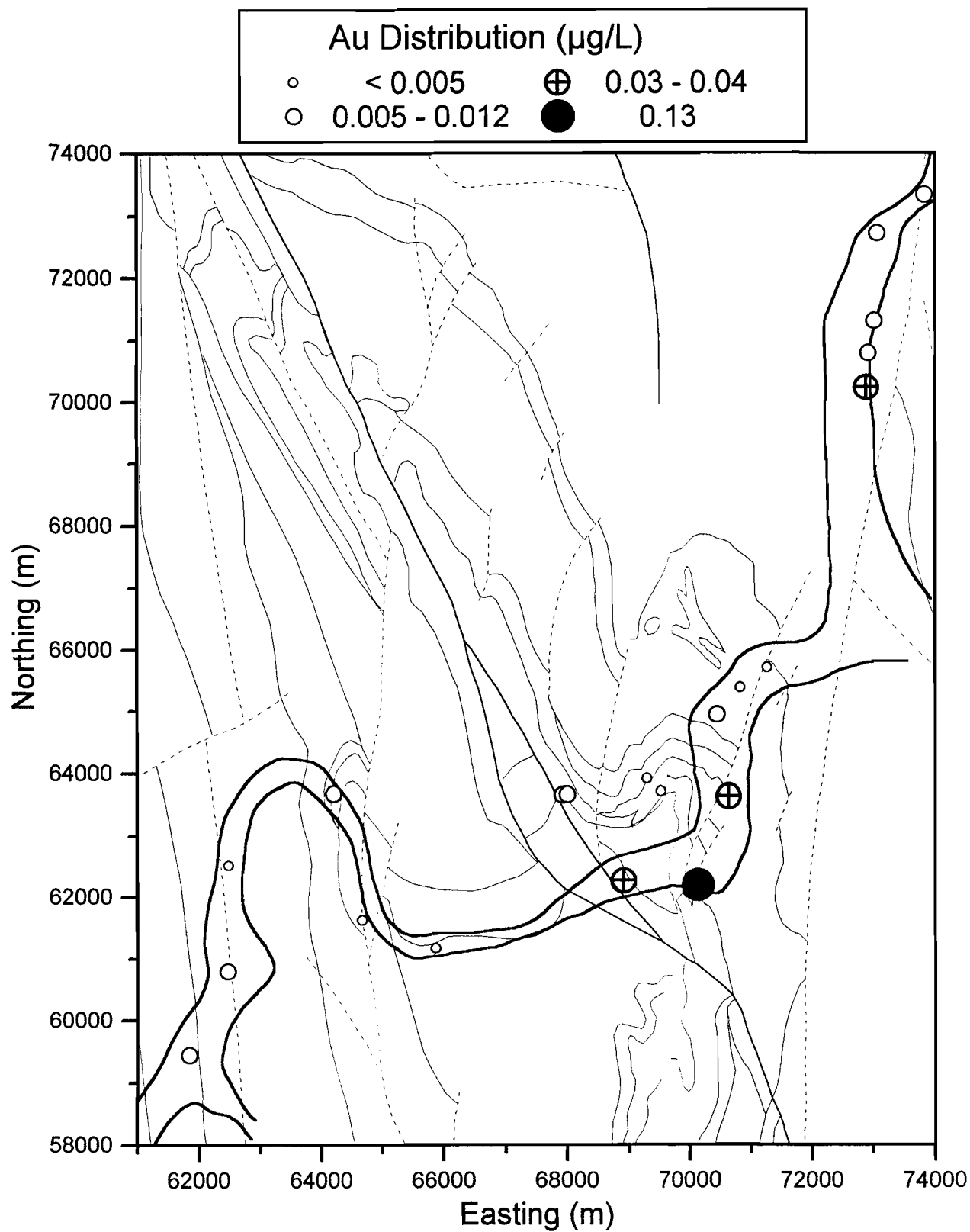


Figure A5.54: Gold distribution in groundwater at Wollubar.

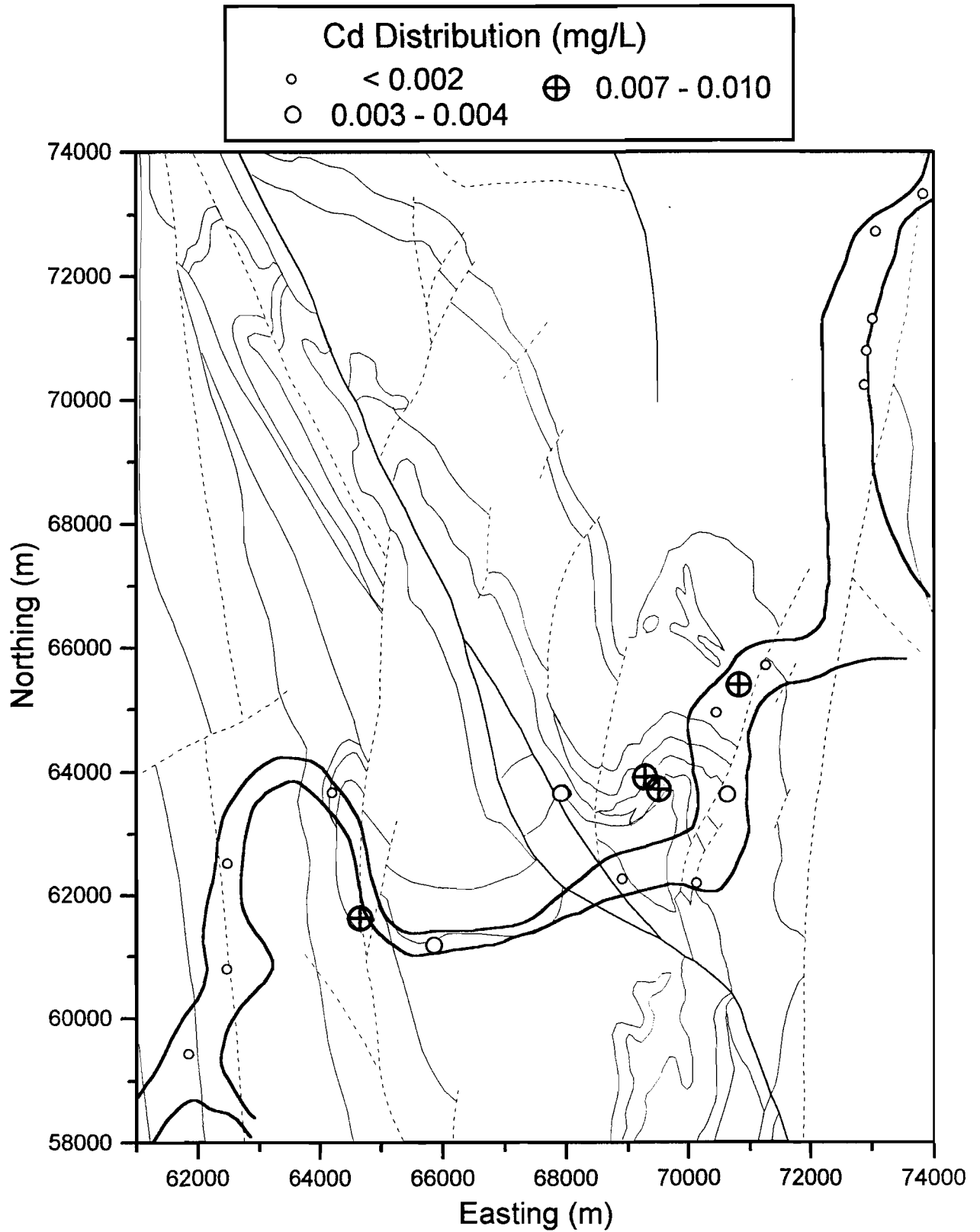


Figure A5.55: Cadmium distribution in groundwater at Wollubar.

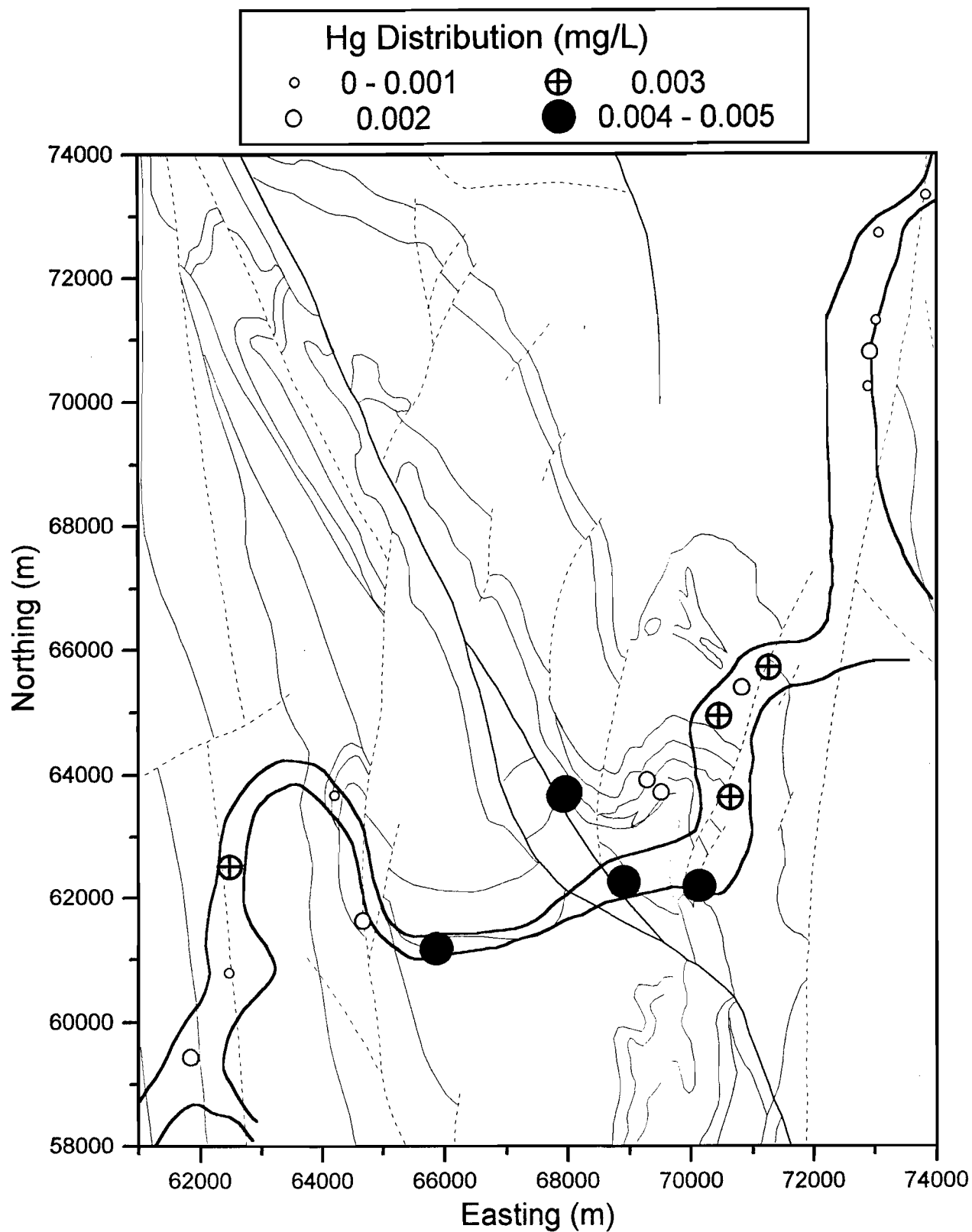


Figure A5.56: Mercury distribution in groundwater at Wollubar.

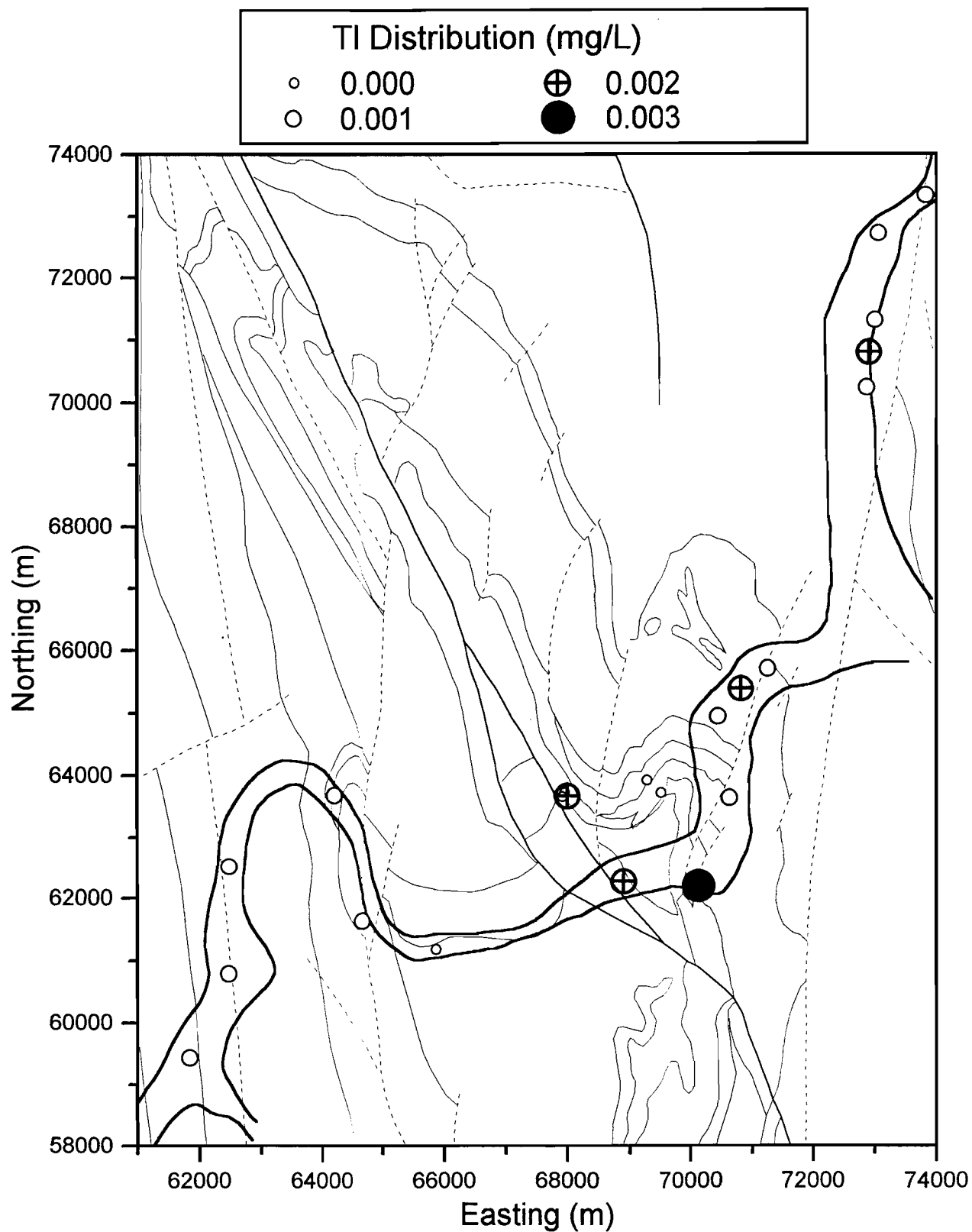


Figure A5.57: Thallium distribution in groundwater at Wollubar.

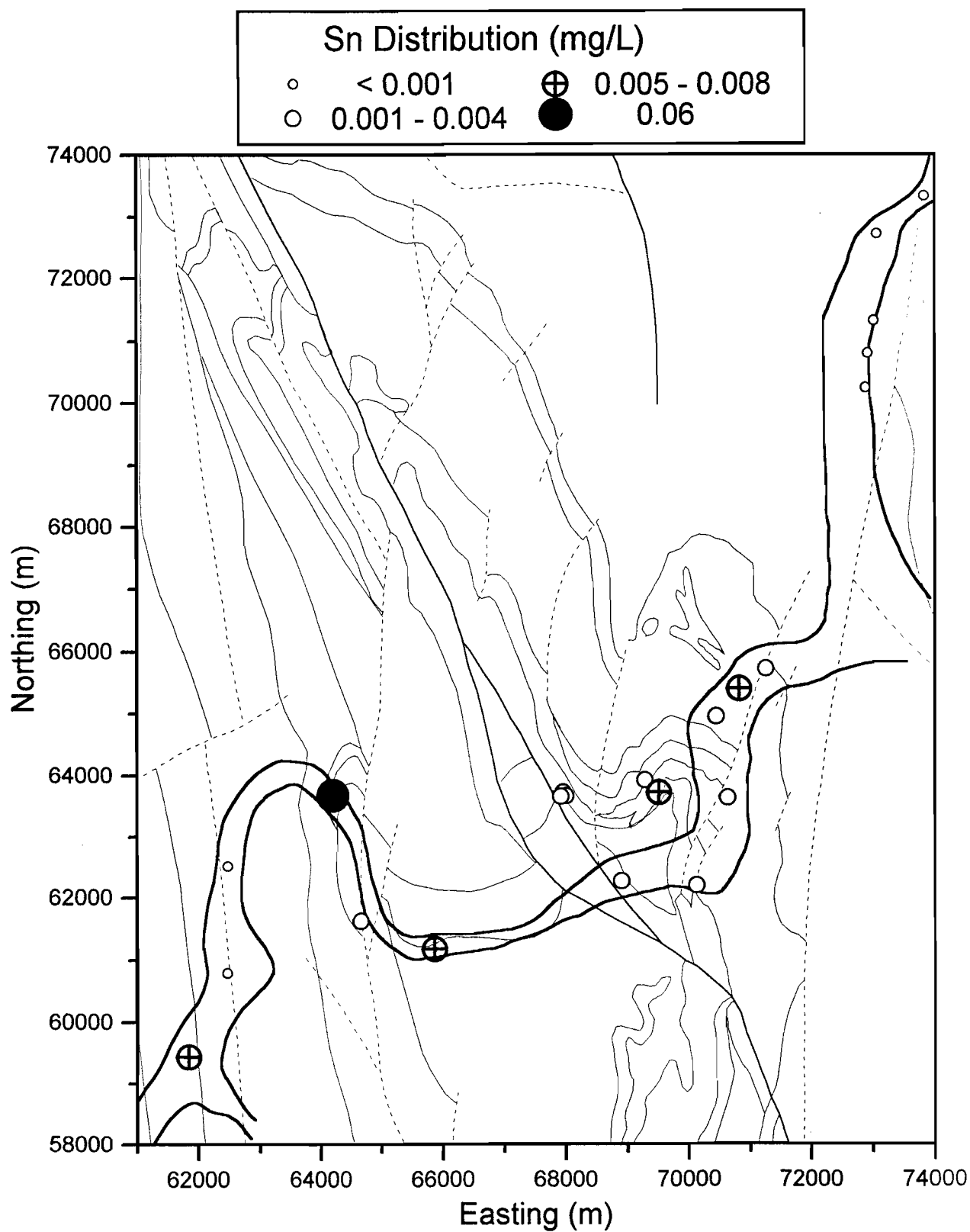


Figure A5.58: Tin distribution in groundwater at Wollubar.

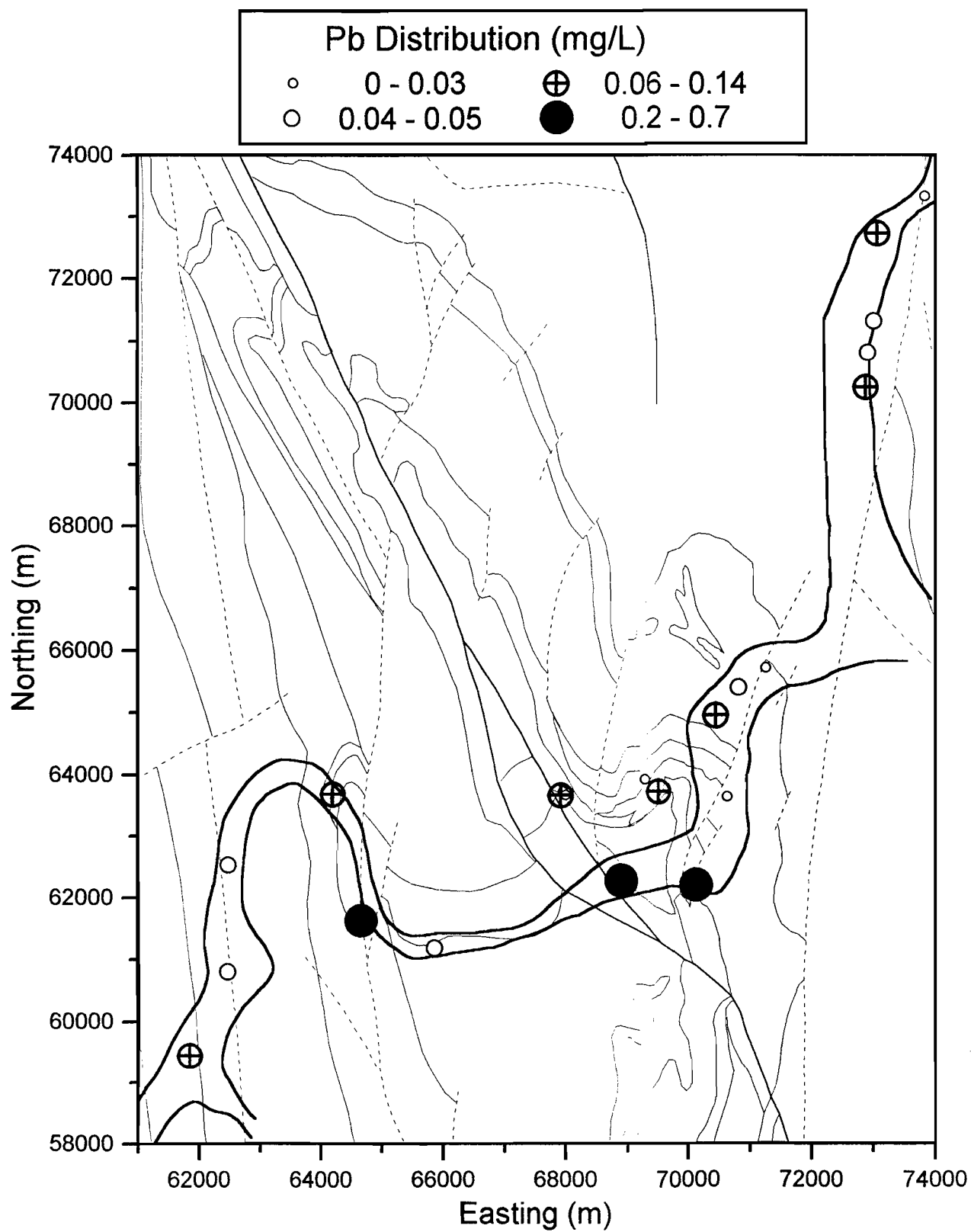


Figure A5.59: Lead distribution in groundwater at Wollubar.

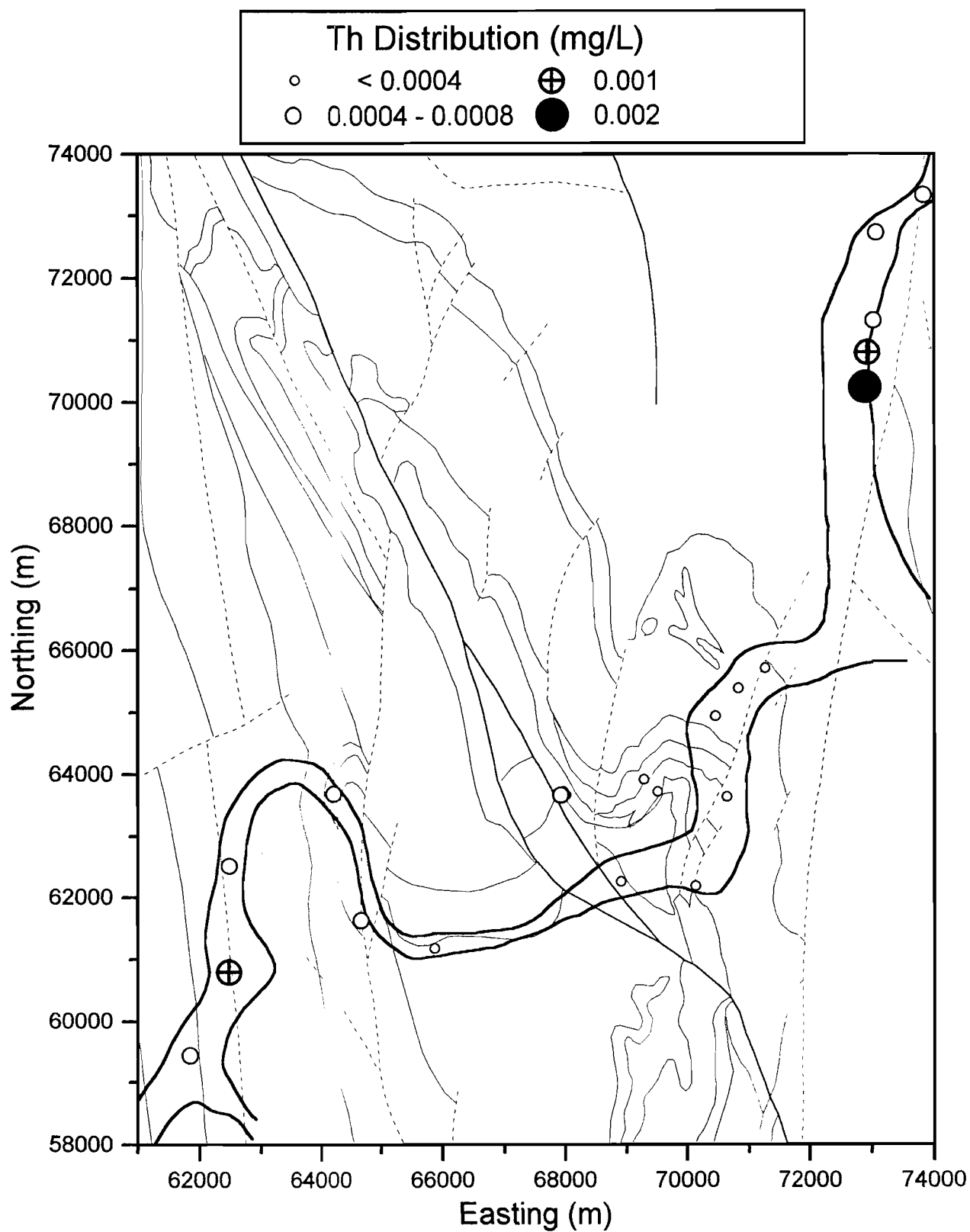


Figure A5.60: Thorium distribution in groundwater at Wollubar.

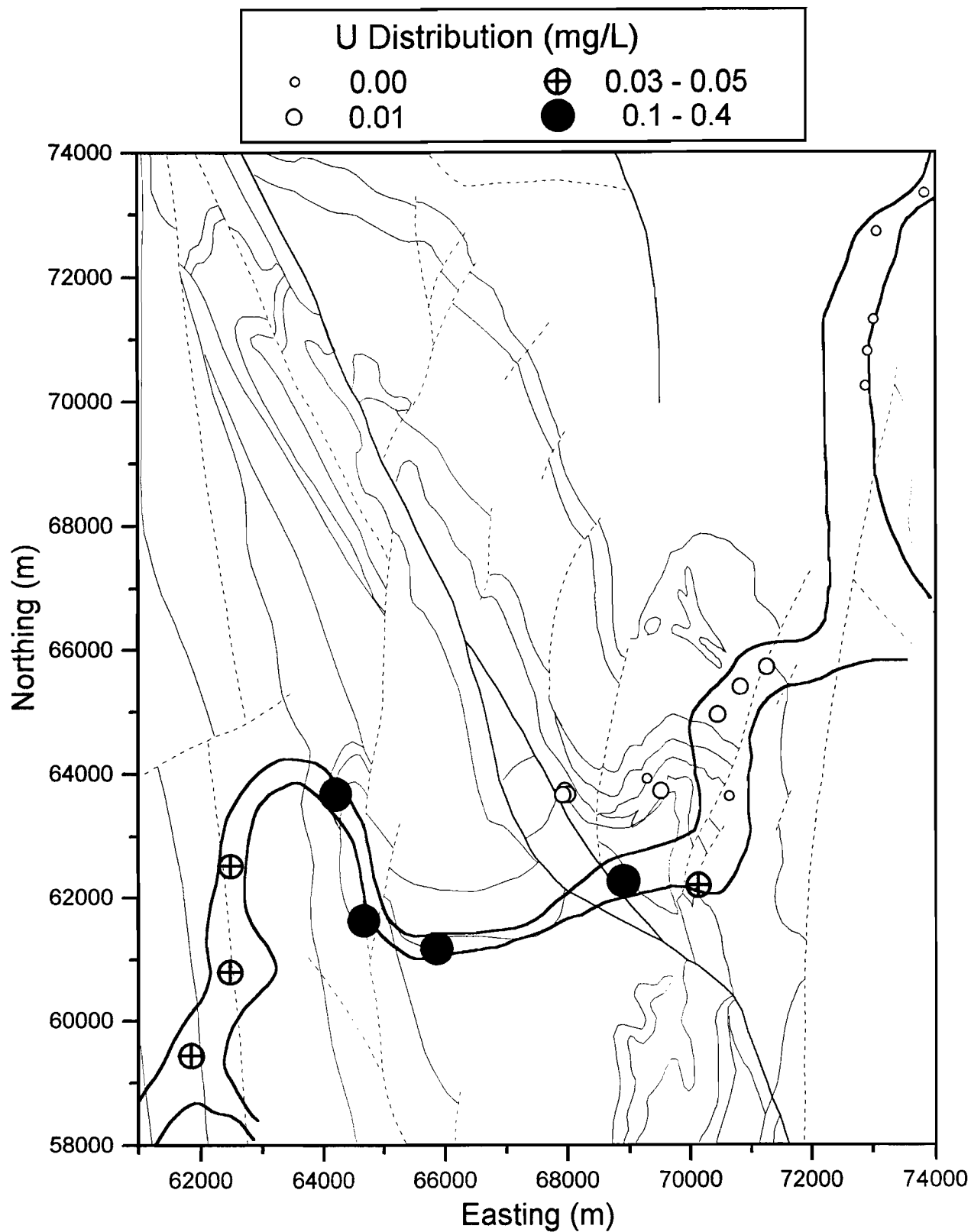


Figure A5.61: Uranium distribution in groundwater at Wollubar.

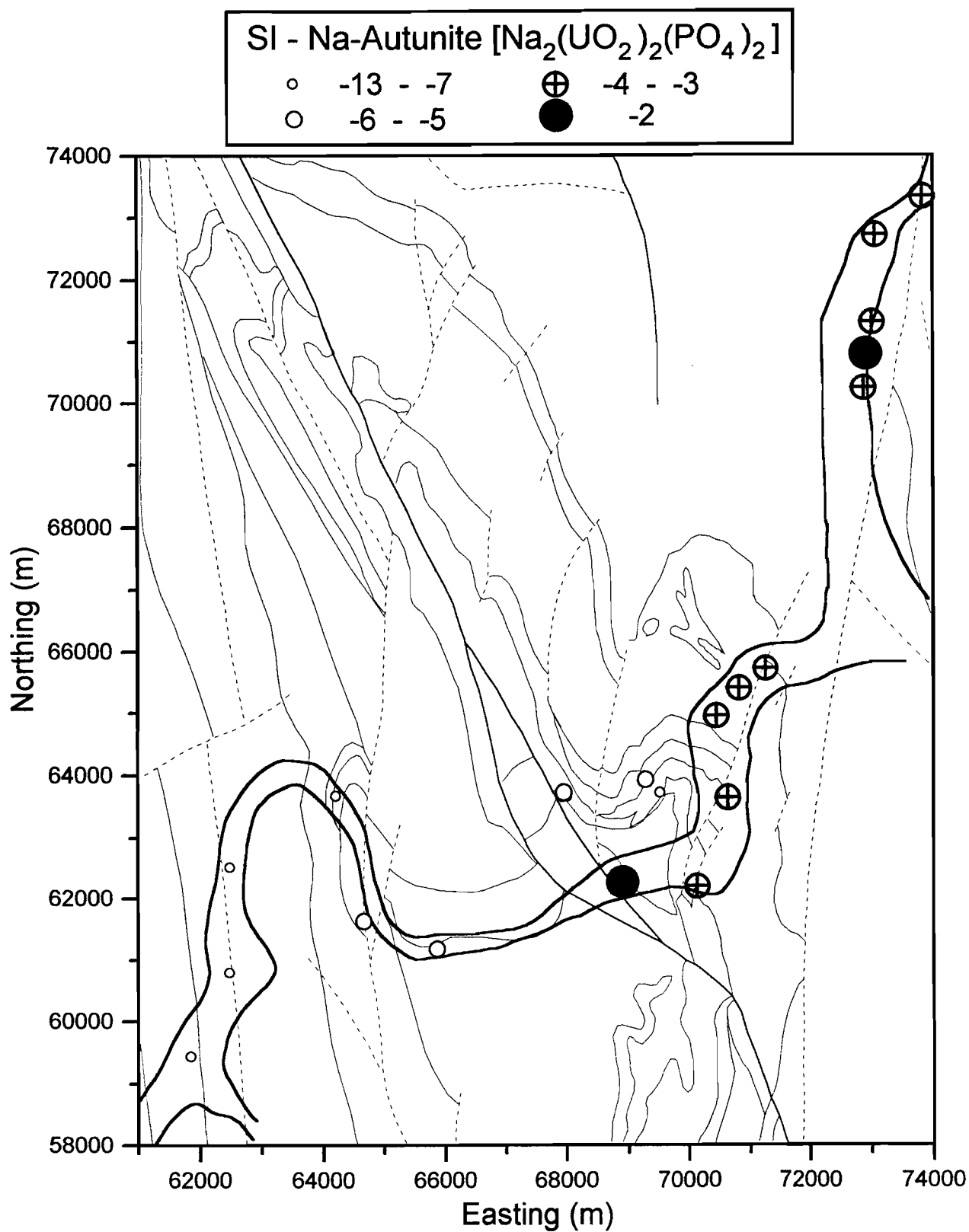


Figure A5.62: Na-Autunite SI distribution in groundwater at Wollubar.