

Groundwater acidification caused by urban development in Perth, Western Australia: source, distribution, and implications for management

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Abstract. A decline in the watertable due to a long period of low rainfall, and the disturbance of sulfidic peat soils by dewatering and excavation in the Perth suburb of Stirling, has led to widespread acidification of groundwater at the watertable in a residential area and contamination of groundwater by arsenic and metals. The acidification has been caused by the oxidation of sulfide minerals within the peat, which contains up to 15% by weight of oxidisable sulfur. Groundwater of pH 1.9 has been measured in shallow monitoring bores in the area, as well as high arsenic (up to 7 mg/L), aluminium (up to 290 mg/L), and iron (up to 1300 mg/L) concentrations. Contaminated groundwater pumped from affected domestic garden bores caused plant deaths in gardens and has given rise to health concerns because of high arsenic and metal concentrations. Drilling has indicated that acidic groundwater generally extends 5–10 m below the watertable, and that deeper groundwater is currently unaffected by contamination. As groundwater forms 70% of Perth's total water usage and sulfide-rich peat soils are common in the region, acid sulfate soil risk maps and management policies need to be developed and implemented as a matter of urgency to prevent similar acidity problems occurring elsewhere in Perth.

Additional keywords: contamination, acidity, arsenic, oxidation, water supply.

Introduction

The city of Perth lies on the Swan Coastal Plain (Fig. 1), an alluvial and aeolian plain largely formed of Quaternary sand and sand/limestone dunes that are up to 100 m thick. The plain lacks surface drainage due to the high permeability of the sediments. The only fresh surface water in the region is in wetlands in inter-dunal depressions which are surface expressions of the watertable of an extensive unconfined aquifer (known locally as the 'superficial aquifer'). Groundwater is extremely important for water supply, and provides about 70% of all water used in the region. There are >130 000 domestic bores in the metropolitan area that are used for garden watering. On average, 25–30% of houses in Perth have domestic bores, and in some suburbs where the watertable is very shallow, almost all houses have bores.

The coastline in Perth does not have mangroves typically associated with acid sulfate soils on the eastern seaboard, and most of the sandy soils in the region have little or no acid generation potential. Although acid sulfate soils of marine or estuarine origin do occur on the Swan Coastal Plain, these only occur in the immediate vicinity of the major estuaries in the region, and are not as widespread as equivalent soils on coastal floodplains in New South Wales and Queensland.

Of greater concern on the Swan Coastal Plain are sulfidic peaty sediments associated with groundwater-dependent

wetlands in the region. These materials contain up to 15% by weight of oxidisable sulfur and have the potential to cause severe groundwater acidification and metal contamination when disturbed by drainage or excavation. These sediments are found at elevations of up to 70 m AHD on the Swan Coastal Plain, and occur in areas that have been designated as groundwater protection areas for public water supply. These soils were first described by Teakle and Southern (1937a, 1937b), who recognised the extreme acidity of this material. A number of wetlands on the Gngangara groundwater mound (Fig. 1) periodically become acidified due to declines in the watertable elevation (McHugh 2000), and these acidic events dramatically change the composition of macro-invertebrate communities that inhabit these wetlands (Sommer and Horwitz 2001).

The most significant incident of acid sulfate soil effects currently recorded in Perth has been caused by the disturbance of peaty wetland sediments associated with new urban developments in the suburb of Stirling. Deposits of sulfidic peat up to 6 m thick occur in this area (Bestow 1981), and this material is an unsuitable foundation for housing and has been locally removed to allow for new residential development. Dewatering and peat excavation for 2 new residential developments and the excavation of artificial lakes by the local government authority caused nearby

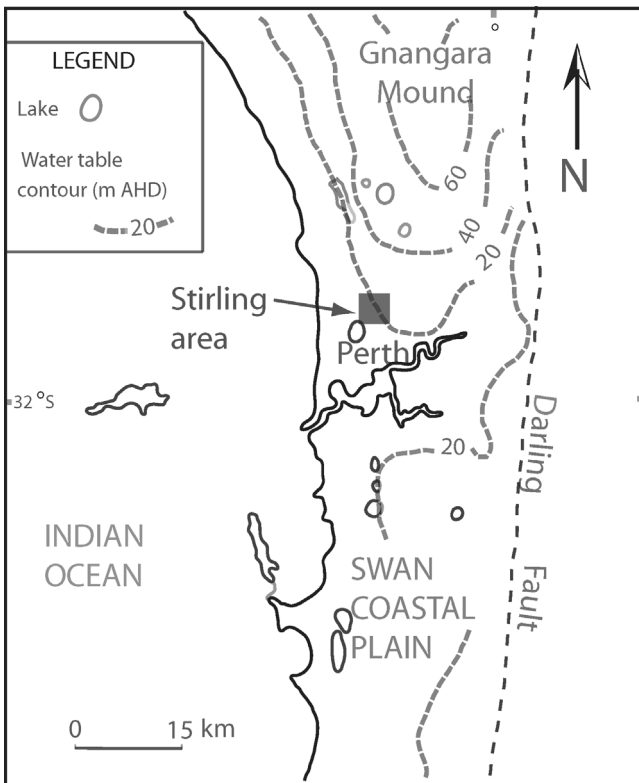


Fig. 1. Location plan.

groundwater pH values to drop as low as 1.9, and as low as 2.4 in excavated lakes in a public park (Fig. 2). The acidic groundwater also contained high concentrations of heavy metals and metalloids. Of particular health concern was the fact that affected groundwater pumped from some garden bores contained arsenic concentrations that exceeded the national drinking water guideline value ($7 \mu\text{g/L}$) by several orders of magnitude; arsenic was detected in garden bores at concentrations up to $800 \mu\text{g/L}$, and up to $7300 \mu\text{g/L}$ in boreholes drilled during investigations in Stirling.

This paper documents the occurrence and distribution of the groundwater acidity and arsenic contamination in Stirling, and examines the implications that this incident may have for groundwater quality in Perth if the watertable continues to decline due to low rainfall and increasing groundwater abstraction.

Methods

Detection of groundwater acidity and arsenic contamination in garden bores and excavated lakes

Investigations in Stirling commenced in January 2002 after the local government authority referred an incident of groundwater acidity in a domestic bore to the Department of Environmental Protection (DEP) for advice. The low pH and high sulfate and metal concentrations in a water sample taken from the bore were indicative of acid sulfate conditions. Additional chemical analysis indicated that the water sample contained $800 \mu\text{g/L}$ of arsenic. A field inspection of the area indicated a number

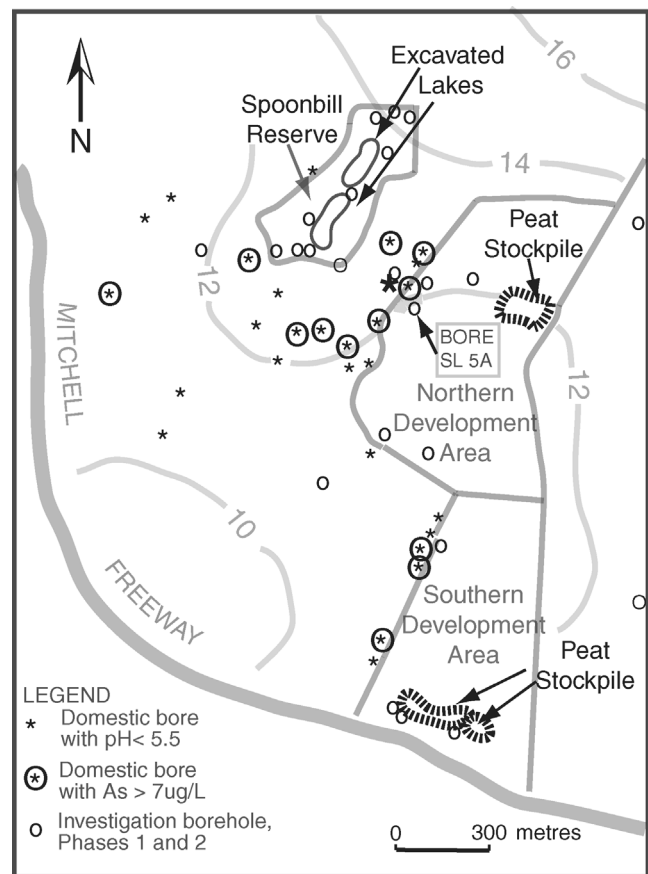


Fig. 2. Location of Phases 1 and 2 investigation bores, acidic garden bores, and acidic garden bores with high arsenic concentrations in Stirling. The regional watertable elevation contours (elevation as m AHD) indicate that groundwater generally flows in a west to south-westerly direction in the area.

of excavated wetlands, including lakes in a public park (Spoonbill Reserve), had pH values of 2.4–3.

As groundwater and surface water in the area was considered to be a risk to public health, the DEP worked closely with the Department of Health to determine the extent and severity of contamination in the area. Chemical analysis of groundwater samples indicated that arsenic concentrations generally did not exceed the drinking water guideline value above pH 5.5. Field pH measurements were used to screen >800 domestic bores to select those that required more detailed chemical analysis. Groundwater samples were collected from domestic bores after several minutes of pumping to purge stagnant water from the bore casing and irrigation pipes. Samples for chemical analysis were sampled in acid-washed polythene plastic bottles provided by a commercial chemical laboratory that was NATA-accredited for the selected analytes. Samples from about 50 of these bores were analysed for heavy metals and arsenic. Arsenic was analysed by vapour generation atomic absorption spectroscopy, lead and cadmium were analysed by inductively coupled plasma mass spectroscopy, and other metals were analysed by inductively coupled plasma-atomic emission spectroscopy.

More than 20 of these bores had arsenic concentrations that exceeded the national drinking water guideline. Additional samples collected from nearby water supply production bores indicated that these were largely unaffected by contamination. Water pumped from public water supply

bores is treated to remove heavy metals and arsenic from groundwater, and therefore this source of water does not pose a risk to public health.

Drilling investigations

Drilling was carried out in 3 phases to determine the characteristics of the peaty sediments, and to determine the severity and the extent of groundwater acidity and contamination in the area.

Initially, 13 investigation boreholes were drilled in February 2002 using a hollow-stem auger fitted with a small screened section. The boreholes were drilled to depths of 13–15 m below ground surface, replicating the typical depths of garden bores in the area. Discrete water samples were collected by pumping through the auger string at 3-m intervals. The equivalent of 3 casing volumes was pumped to waste, and then water samples were collected and pumped water was tested for pH and electrical conductivity (EC) in the field. Samples were collected in acid-washed polythene bottles and stored on ice in ice-chests for up to 4 h before delivery to a chemical laboratory for filtering (0.45 μm) and chemical analysis. These samples were chemically analysed for major ions, and for heavy metals and arsenic. The boreholes were constructed with fully slotted 50-mm-diameter PVC casing to allow groundwater pH to be measured on an ongoing basis.

The main purpose of the second phase of drilling was to investigate the stratigraphy of the peaty sediments. Investigation boreholes were drilled to depths of up to 15 m at 15 sites on transects across the peatland at Stirling using a direct-push drilling technique. At each site, 25-mm-diameter sediment cores were extruded into airtight clear plastic tubes that were capped to prevent oxidation of the material. The sediment-filled tubes were stored on ice for up to 4 h before being frozen. The sediments were then dried in a rapid-draft oven at 85°C for 48 h for long-term storage. Material from the cores was analysed for Total Carbon and Sulfur using an Eltra 4000 Carbon/Sulfur Determinator, and for total organic carbon using a Dohrman Total Organic Carbon Analyser. Potential and actual acidity measurements on core material were made using the chromium-reducible sulfur, peroxide oxidisable sulfur, total potential acidity, total actual acidity, and total sulfidic acidity methods described in Ahern *et al.* (1998).

Additional direct push drilling was carried out to obtain groundwater quality data at each site. The groundwater was sampled through a 0.3-m-wide extruded screen at various depth intervals using a peristaltic pump and was sampled in the same manner as for the hollow stem auger investigations.

The third phase of drilling was focussed on determining the extent and severity of groundwater contamination in the vicinity of excavated lakes on the Spoonbill Reserve. Boreholes were drilled using the direct-push method to collect sediment cores and to sample groundwater at various depths in the aquifer, and 25-mm-diameter monitoring bores were constructed at these drilling sites (Fig. 3).

Stockpile sampling

Forty samples were collected from peat stockpiles on the development sites to investigate the mineralogy of peat and ferricrete from the excavation sites to be examined. The mineralogy of 21 stockpile samples was investigated using X-ray diffraction techniques, and by making spot energy dispersive spectrum (EDS) measurements with a scanning electron microscope (SEM).

Results

Metal and arsenic contamination in acidified garden bores

Garden bores with pH <5.5 typically had elevated metal and arsenic concentrations (Table 1). Although groundwater pumped from these bores is not used for drinking, the high

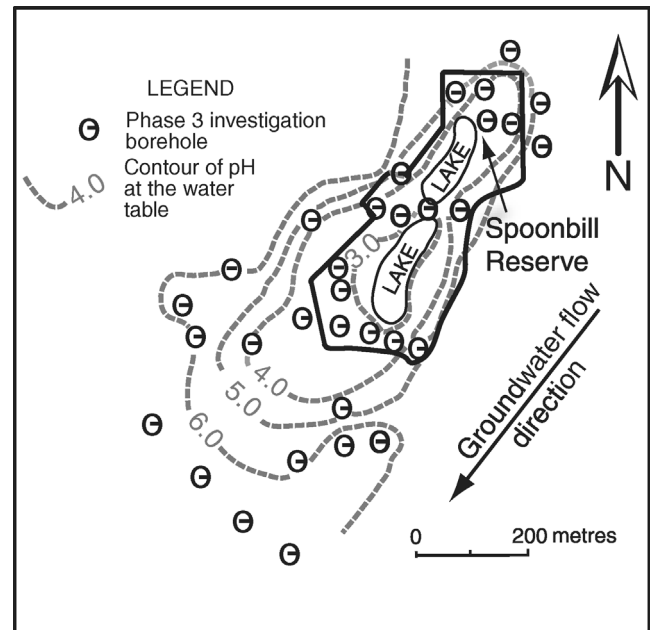


Fig. 3. Location of Phase 3 investigation bores and the extent of acidic groundwater in the vicinity of Spoonbill Reserve.

arsenic concentrations in some bores were of concern to the Western Australian Department of Health because of the risk of uptake in home-grown fruit and vegetables irrigated with the contaminated water. However, tests of garden produce carried out by the Department of Health indicated that this was not occurring. It is likely that most of the plant deaths in gardens irrigated by affected bores were caused by the very high aluminium concentrations in groundwater. At some residences, the entire garden was killed by contaminated groundwater, which prevented further use of the bore.

Bores affected by acidic groundwater were shallow, and were generally constructed at depths of <10 m below the watertable.

Distribution of groundwater acidity and arsenic contamination

The distribution of domestic bores affected by low pH values indicated that there were several factors contributing to groundwater acidity in the area. These included: dewatering to allow peat excavation for urban development; the stockpiling of peat before removal from the development sites; the historical deposition of acidified material upgradient of lakes in a public park (Spoonbill Reserve) in a residential area; and a regional trend of a declining watertable due to generally low annual rainfall in Perth since 1975 (Salama *et al.* 2002). Figure 2 shows that there are clusters of domestic bores that have low pH values immediately downgradient in the direction of groundwater flow from the residential development sites and the lakes in Spoonbill Reserve. Additional drilling and sampling of domestic bores

Table 1. Metal, arsenic and sulfate concentrations in garden bores with a pH <5.5 (all concentrations are in units of mg/L)

Sample ID	pH	As	Al	Pb	Zn	Ni	SO ₄ ²⁻	Fe
01E0839/001	2.6	0.23	180	0.02	0.16	–	2720	810
01E0839/002	3.4	0.8	24	0.009	0.11	–	722	190
01E0839/003	2.7	0.021	290	–	0.69	–	4430	1300
01E0839/004	3.8	0.061	48	0.054	0.085	–	922	180
01E0912/004	2.4	0.018	0.4	<0.0005	<0.05	0.01	602	120
01E0984/001	3.8	0.031	3.3	0.0041	0.08	0.01	287	8
01E0965/001	2.9	0.007	48	0.015	0.21	0.04	1110	310
01E0839/005	3.8	0.011	11	0.0021	0.045	0.04	497	41
01E0839/006	3.6	0.022	22	0.0038	0.033	–	541	87
01E0911/004	3.0	0.011	2	<0.0005	<0.02	0.01	156	11
01E0965/004	3.0	0.17	83	0.002	0.22	0.02	1840	440
01E0965/005	3.4	0.064	62	0.002	0.13	0.02	1150	190
01E0958/007	4.5	0.038	4	<0.0005	0.03	0.01	306	66
01E0957/001	2.5	0.005	39	0.025	1.2	0.07	775	140
01E1044/001	5.0	0.001	58	0.22	5	0.39	805	17
01E0957/002	2.6	0.014	26	0.002	0.15	0.14	467	99
01E0957/005	2.6	0.016	22	0.024	0.1	0.02	833	150
01E0957/006	2.9	0.022	6	0.008	0.02	0.01	317	51
01E0958/001	3.8	0.009	2.6	0.007	0.12	0.01	394	79
01E0958/002	4.3	0.064	11	0.0008	0.03	0.01	520	87
01E0958/005	4.5	0.1	3.3	<0.0005	0.02	0.02	867	170
01E0958/006	4.1	0.029	3.1	0.0003	0.03	0.01	397	33
01E0911/001	3.5	0.013	16	0.008	0.03	0.01	475	73
01E0957/007	2.6	0.001	40	0.003	0.11	0.13	1110	51

upgradient of the Spoonbill Reserve (Willis-Jones 2004), and of domestic bores upgradient of the new residential developments by the DEP have indicated that groundwater was not affected by acidity in these areas. Additional drilling and groundwater sampling on Spoonbill Reserve carried out during Phase 3 of this study identified a distinct plume of acidic groundwater (Fig. 3) emanating from disturbed sulfidic peat in the northern part of the reserve. The plume is currently about 800 m long, and passes through the 2 lakes on Spoonbill Reserve and is affecting domestic bores to the south of the reserve.

On 6 August 2003, 5 t of liquid containing 30% calcium hydroxide was added in single dose to the northern lake on Spoonbill Reserve to determine the rate that acid was being input to the lakes by groundwater flow. The pH of this lake initially rose to about 11.5, but then progressively declined until it reached its pre-test pH value (3.2) on 6 September 2003. On the basis of this test, the rate of acid input was estimated to be equivalent to about 4 kg of CaCO₃ per day (Willis-Jones 2004). During the test period, monitoring bores downgradient of the Spoonbill Lakes were sampled on a daily basis to detect the breakthrough of solutes released into groundwater by the test. Concentration–time data for calcium, aluminium, sulfate, magnesium, and sodium from 3 monitoring bores indicated that the average rate of groundwater flow in the area was about 1.1–1.6 m/day in a southwesterly direction.

Drilling and groundwater sampling down-gradient of peat stockpiles and excavated lakes indicated that groundwater

was typically acidic to 3–5 m below the watertable and that pH values generally returned to background values of about 6–7 at greater depths. Table 2 illustrates how the quality of groundwater varies with depth in one of these boreholes, and shows how arsenic and most metal concentrations are highest near the watertable and rapidly decline in magnitude with depth in the aquifer.

In addition to arsenic, acidic groundwater in Stirling contains high concentrations of metals, particularly iron (up to 1300 mg/L) and aluminium (up to 290 mg/L). Acidic groundwater also contains high concentrations of sulfate (up to 4400 mg/L), and chloride/sulfate ratios were generally <1 and as low as 0.05. Water quality problems in acidic bores were generally remedied by deepening the bores by at least 10 m.

Phase 2 of the Stirling program sampled the aquifer to a maximum depth of 15.6 m and confirmed that the waters are typically acidic (i.e. pH <5, to as low as 2.5), with EC values ranging between 0.483 and 4.4 mS/cm and redox values between –250 and 320 mV. The groundwater is dominated by Cl[–]–SO₄^{2–}, with Na⁺ and Ca²⁺ as the major cations. There is a moderate to strong negative correlation for groundwater pH : EC and pH : redox ($R = -0.49$ and -0.56 , respectively). The high concentrations and strong correlation between total Fe, Fe²⁺, SO₄^{2–}, and low pH are strong indicators that sulfides are being oxidised in the groundwater flow path.

The Phase 2 investigation confirmed the relationship between low pH and high contaminant levels, mainly coincident at the watertable. High and occasionally extreme

Table 2. Variation of groundwater quality with depth in borehole SLA5 (see Fig. 2 for location)
The watertable is about 3 m deep at this site

Depth (m below ground)	pH	EC (mS/m)	As ($\mu\text{g/L}$)	Al (mg/L)	Cd ($\mu\text{g/L}$)	Cr ($\mu\text{g/L}$)	Pb ($\mu\text{g/L}$)	Ni ($\mu\text{g/L}$)	Fe (mg/L)
3.6	2.6	504	7300	230	72	310	17	150	1200
6.6	3.4	381	280	160	<5	140	2	130	1000
9.6	3.8	429	17	200	<5	100	5	290	1200
12.6	5.6	142	24	0.21	<5	<20	<0.5	<10	110
15.6	4.4	147	25	2.8	<5	<20	7	50	180

concentrations of several trace elements and heavy metals included maxima for As (900 $\mu\text{g/L}$), Al (133 mg/L), Fe (888 mg/L), Cd (1935 $\mu\text{g/L}$), Pb (221 $\mu\text{g/L}$), Cr (352 $\mu\text{g/L}$), Ni (396 $\mu\text{g/L}$), Se (16.8 $\mu\text{g/L}$), Ba (148 $\mu\text{g/L}$), Hg (2.73 $\mu\text{g/L}$), and Si (117 mg/L).

Mineralogy of sulfides and oxidation products in peat

The presence of sulfide minerals below the watertable in areas affected by acidity was inferred from positive field and laboratory peroxide oxidation and chromium-reducible sulfur tests on sediments excavated from below the watertable, and the presence of jarosite mottles in shallow soil profiles. X-ray diffraction measurements have indicated that peat contains pyrite (McHugh 2000; Angeloni 2003) and marcasite (Teakle and Southern 1937a, 1937b). The iron oxide precipitates in acidic lakes consist mainly of the mineral schwertmannite (R Fitzpatrick, pers. comm.). Analysis of the peat from the Roselea development site (Fig. 2) indicated that it contained up to 15% oxidisable sulfur. The highest arsenic concentrations in soil, as well as total sulfur and reduced inorganic sulfur values, typically occur near the base of the peat sequence, covering the transition into the underlying unconsolidated sands (Table 3), indicating that the oxidation of pyrite or other iron sulfide minerals is the most likely source of the arsenic and possibly other groundwater contaminants. Spot EDS analyses made with a SEM on pyrite framboids in core samples also suggest that most of the arsenic is associated with pyrite in soil materials (Angeloni 2003). This is supported by strong correlations between arsenic and chromium-reducible sulfur levels in sediments ($R = 0.81$), and arsenic and iron concentrations ($R = 0.86$).

Elevated arsenic concentrations of up to 231 mg/kg are also associated with secondary ferricrete units within the peat sequence, which include manganiferous, iron hydroxysulfate-carbonate assemblages.

The dominant iron oxide minerals detected in material taken from peat stockpiles were goethite, hematite, and a variety of iron-manganese oxyhydroxides. The carbonate minerals siderite and rhodochrosite were also commonly detected in partially oxidised peat and in ferricretes.

Variation of groundwater quality with time

Land use within the Stirling area has changed substantially over the last 40 years, and there is some evidence that groundwater quality has changed in response to increasing urban development within the area. Although the data are very limited within the area currently affected by acidification, the available information suggests that in 1980, iron, arsenic and total dissolved solids (TDS) concentrations were much lower, chloride/sulfate ratios were much higher, and the average pH was less acidic in shallow bores in this area than now (Table 4).

Stirling is also located within the Gwelup Underground Water Pollution Control Area (UWPCA), where a number of production bores pump water from the superficial aquifer for public water supply. Many parts of the Gwelup UWPCA are covered by peaty soils and these are under intense development pressure. There was a period of particularly rapid urban growth in the 1970s (Barber *et al.* 1996), and Martin (1982) attributed increases in sulfate, iron, and TDS concentrations in water pumped from Gwelup production bores at this time to a response of groundwater quality

Table 3. Chemical analysis of cored soil from Spoonbill Reserve to the north of the excavated lakes (after Angeloni 2003)

Depth (m)	Soil pH (1:5 paste)	Core description	Total C (%)	Total S (%)	Cr-reducible S (mg/kg)	As (mg/kg)	Fe (%)
0.0		Topsoil (sandy fill)					
0.5	3.9						
1.0	3.3	Sandy peat	29.1	4.0	0.4	94	1.8
1.5		Ferricrete with siderite	4.2	4.6	1.2	269	4.0
2.0	3.8	▽ Watertable (2.25 m) Grey sand	3.0	8.8	2.5	300	6.9
2.5	5.5		0.4	3.8	0.8	134	2.8
3.0							

Table 4. Comparison of historical and recent shallow groundwater quality data from areas affected by acidification in Stirling (all concentrations are in units of mg/L)

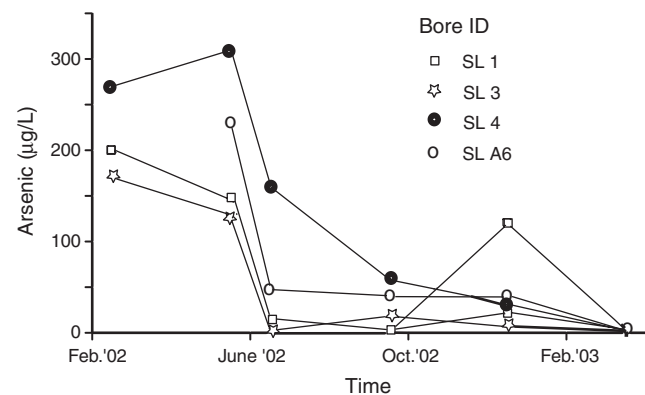
Parameter	Summary of 1980 data (source: Bestow 1981)		Summary of current data (source: Phase 1, this study)	
	Mean	Range	Mean	Range
pH	6.8	6.6–7.2	5.2	2.5–6.9
Cl ⁻ /SO ₄ ²⁻	13	1–31	0.6	0.1–2.7
TDS	460 mg/L	272–760 mg/L	780 mg/L	290–2800 mg/L
As	<0.02 mg/L	All <0.02 mg/L	0.3 mg/L	<0.01–7.3 mg/L
Al	Not analysed	Not analysed	21 mg/L	0.03–230 mg/L
Pb	<0.02 mg/L	All <0.02 mg/L	0.01 mg/L	<0.0005–0.087 mg/L
Fe	6	1.1–11 mg/L	130 mg/L	0.1–1200 mg/L
No. of samples		4		40

to the development of land for housing and commercial activities. He suggested that the source of the dissolved chemical constituents was the oxidation of sulfide minerals in soil profiles disturbed by development. A regional groundwater quality investigation carried out by the Water Authority in the mid 1980s (Cargeeg *et al.* 1987) found that sulfate concentrations in groundwater in Gwelup commonly exceeded 100 mg/L, whereas concentrations in much of the Perth metropolitan were <100 mg/L. The study also found that chloride-sulfate ratios in groundwater in Gwelup were commonly <0.5 at this time, compared with the urban groundwater average of about 2 in Perth (Davidson 1995). The source of the sulfate in this study was attributed to a combination of sulfide oxidation and excessive fertiliser use.

Despite both of these studies recognising that sulfide oxidation could be occurring in the Gwelup UWPCA since the 1970s, there has been no evidence of groundwater acidification until now. This could partly be due to the fact that there are only a limited number of shallow monitoring bores in the area that are routinely monitored (although the water supply bores are monitored on a continuous basis, they are pumping water from too deep in the superficial aquifer to be affected by groundwater acidity), but may also indicate that the rate of oxidation has generally not been high enough to affect groundwater pH until recently. The factors that may have accelerated pyrite oxidation in Stirling include:

- Aggressive dewatering in the 2 development areas to lower the watertable by up to 6 m to allow the excavation and of peat to provide a stable surface for building;
- Stockpiling of highly sulfidic peat for long periods on the development sites (Fig. 1), allowing extensive sulfide oxidation to take place at the surface of the stockpiles;
- Excavation of lakes for public amenity within peat in a public park (Spoonbill Reserve, Fig. 1); and
- A long period of low winter rainfall that has seen the watertable in the area drop 2 m below its average level.

Dewatering and peat removal has ceased in many parts of the two residential sites, and peat has been replaced by clean sand. Although groundwater pH values on the

**Fig. 4.** Variation of arsenic concentrations with time beneath the southern new residential development site.

Hamilton Lakes estate (Fig. 2) in particular have moderated and now generally exceed 6, arsenic concentrations in some monitoring bores (Fig. 4) still exceed 100 µg/L. There is a declining trend in both arsenic and sulfate concentrations in many monitoring bores, but it is not known whether arsenic concentrations will return to their pre-development levels.

Discussion—implications for management

In addition to potential effects on public health, the acidification of groundwater and drainage from the new urban developments in Stirling has the potential to impact on nearby conservation-category wetlands, and there is also the risk of long-term impacts on subsurface infrastructure within the development areas. The acidification problems have been caused by deficiencies in the environmental approvals process and a lack of a comprehensive planning policy that addresses acid sulfate soils in Western Australia. The regulatory process needs to be changed to ensure that similar problems do not occur again in the State. As an interim measure, the DEP has released draft planning guidance on acid sulfate soils to all local government authorities in the State using existing geological and soil mapping to indicate areas where there is a significant risk of these soils occurring. State Cabinet is

currently considering a submission from the DEP for a State-wide acid sulfate soil risk mapping and policy development program based on similar work that is currently being carried out in South Australia.

Of broader concern is the issue that sulfide oxidation in many parts of the Gwelup UWPCA may have been occurring since the 1970s with the rapid expansion of urban development in the area at that time. Although bores used for public water supply are monitored regularly and treated to remove arsenic and other contaminants, there are a large number of unmonitored domestic bores in the area that could potentially be subject to arsenic contamination, and this needs to be assessed as a matter of urgency. Although the health risks from arsenic contamination are very low provided the groundwater is not used for drinking, many residents drink water from their bores on a regular basis, despite warnings from the Department of Health not to do so. There are also a large number of households on rural fringes of the Perth metropolitan area that do not have access to scheme water and rely on groundwater from their own bores as a source of drinking water. Many of these areas also have similar peaty soils to the Gwelup UWPCA, and therefore are also at risk of arsenic contamination. Residents who rely on groundwater as a drinking supply need to be aware of this risk, and should test their bores for arsenic on a regular basis.

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