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An overview of changes in soil acidity in reflooded acid sulfate soil environments around Lakes Alexandrina and Albert, South Australia

Prepared for: Department of Environment, Water and Natural Resources, as part of the Coorong, Lower Lakes and Murray Mouth Program

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EXECUTIVE SUMMARY

Between 2007 and mid 2010, reduced inflows from the River Murray to Lakes Alexandrina and Albert (the Lower Lakes) in South Australia had resulted from the persistent drought in the Murray-Darling Basin. In the Lower Lakes, the combination of decreasing water levels and gently sloping near-shore lake beds caused large expanses of previously inundated sediments and subaqueous soils to be exposed. With continued lowering of water levels, Acid Sulfate Soil (ASS) materials became progressively oxidised to greater depths in the soil profiles.

Prior to the drought, median soil pH in the Lower Lakes was circumneutral and displayed a narrow range. Drought caused median and interquartile pH ranges to decrease significantly. However, soil acidification along the margins of the Lakes was very variable and largely related to heterogeneity of the soil types and ASS parameters as well as geomorphological controls.

For the purposes of this study, selected study sites from around the Lower Lakes were examined to assess rates of change in ASS environments to help explain some of the processes occurring within soil profiles during drought and subsequent inundation. Data considered for this study were collected between August 2007 and February 2013.

Following inundation, in late 2010, median pH increased significantly. However, many of the soils remained acidic up to the end of the monitoring period (2013) and a number of hot spots were identified in some parts of the lakes (e.g. Dog Lake, Boggy Lake, Campbell Park, Finniss River and the northern side of Lake Albert) where high Net Acidity (NA) and incubation pH indicated high acidification hazard potential.

Rates of recovery were complex, nonlinear and varied spatially and with depth highlighting a highly heterogeneous system that was partly controlled by soil texture: clays were less easily flushed and tended to have higher sulfide contents and net acidity. Where sand dominated (mainly unreactive quartz grains) the soil profile, a more rapid impact occurred due to little mineral buffering. However, sands often contained less total acidity than clays and were more rapidly/easily flushed following inundation. Slow dissolution of jarosite may have buffered soils at low pH for long periods of time and, causing slow recovery rates. This is particularly the case in clay soils with higher Chromium Reducible Sulfur (CRS) and low permeability.

Sulfide contents decreased during the drought, and although some reformed following inundation, in many cases concentrations were less than originally present. Soils are in a transient state and the build up of sulfide is likely to continue under saturated conditions.

The form of acidity changed over time. A general ‘ideal’ sequence during soil recovery ASS systems is:

- Acidity from jarosite buffers system (until consumed) to low pH maintaining Titratable Actual Acidity (TAA).
- Neutralisation of TAA as alkalinity is generated, mainly by neutralisation and reduction processes (O, NO_3, Mn, Fe).
- Formation of reduced S species leading to formation of sulfide minerals which act as a store of acidity.

Recovery was more significant in the upper soil layers, and often the middle layers remained acidic. The reasons for this are several fold:

- Higher labile organic matter in surface soils which support reduction processes and the consequent generation of alkalinity.
- Infiltration during refilling of fresh surface water generating a downward flux of acidity and contaminants from surface layers.

- The common occurrence of more sandy sediments at the surface.

There was little or no loss of acidity (actual or stored) from the soils, although data suggests some local transport at the cm scale e.g. flushing of acidity downwards through the profiles in sands. For the latter, however, sulfides are now beginning to form in surface layers. The stores of actual and potential acidity have simply been cycled within the soils.

In many areas, soil pH levels have not returned to pre-drought levels and acidification hazard remains high around much of the Lower Lakes. Additionally, the onset of future acidification may be more rapid in areas where ANC has been lost. If water levels return more slowly than occurred following the Millennium Drought, there is the potential for:

- greater decreases in surface water alkalinity,
- the complete loss of alkalinity and buffering in more areas
- and acidification of stagnant, ponded water bodies around the margins of the Lakes.

It is recommended that limited biannual monitoring of AAS environments should be undertaken at potential acidification hot spots to assess when and if a return to pre-drought conditions have been attained.

1. INTRODUCTION

1.1 Background

From 2007 until mid 2010, reduced inflows from the River Murray to Lakes Alexandrina and Albert, South Australia occurred as a consequence of persistent drought in the south east Australia including the Murray-Darling Basin. The combination of decreasing water levels and gently sloping near-shore lake beds caused large expanses of previously inundated sediments and subaqueous soils to be exposed to the atmosphere. With continued lowering of water levels, acid sulfate soil (ASS) materials became progressively oxidised to greater and greater depths in the soil profiles. The resultant formation of sulfuric materials (pH < 4) produced significant soil, water quality and ecological problems.

Increased rainfall within the Murray-Darling Basin catchment from March 2010 caused a rapid rise in water levels and inundation of sulfuric materials that had formed in the previously dried margins of the Lower Lakes.

This report examines data collected as part of a number of ASS monitoring projects that were carried out around the margins of Lake Alexandrina, Lake Albert and adjacent tributaries between November 2007 and February 2013 (Baker *et al.* 2010; Baker *et al.* 2011; Baker *et al.* 2013a; Baker *et al.* 2013b). During this period, soil sampling was undertaken on eight occasions to assess the impacts of drought on ASS formation and the subsequent extent and rate of inundated soil neutralisation. These investigation encompassed 24 study areas that were generally representative of the diverse environments encountered around the Lakes and based on previous ASS investigations undertaken in the region since 2007 (Figure 1-2)(e.g. Fitzpatrick *et al.* 2010b; Fitzpatrick *et al.* 2008a; Fitzpatrick *et al.* 2008b; Fitzpatrick *et al.* 2009; Fitzpatrick *et al.* 2008c).

Water levels varied considerably during the monitoring period, falling from approximately +0.75 m (AHD) in 2007 to less than -1.00 m (AHD) and -0.75 m (AHD) in Lakes Alexandrina and Albert respectively in 2009 (Figure 1-1). ASS monitoring commenced in November 2009, when water levels in the Lakes were at their lowest, and continued until February 2013 (samplings a to g). Limited pre-monitoring (pm) sampling was undertaken in 2007 and 2008. Generally, "pm" samples included in this report were collected under subaqueous conditions and the data generated represents the only available pre-drought ASS baseline conditions.

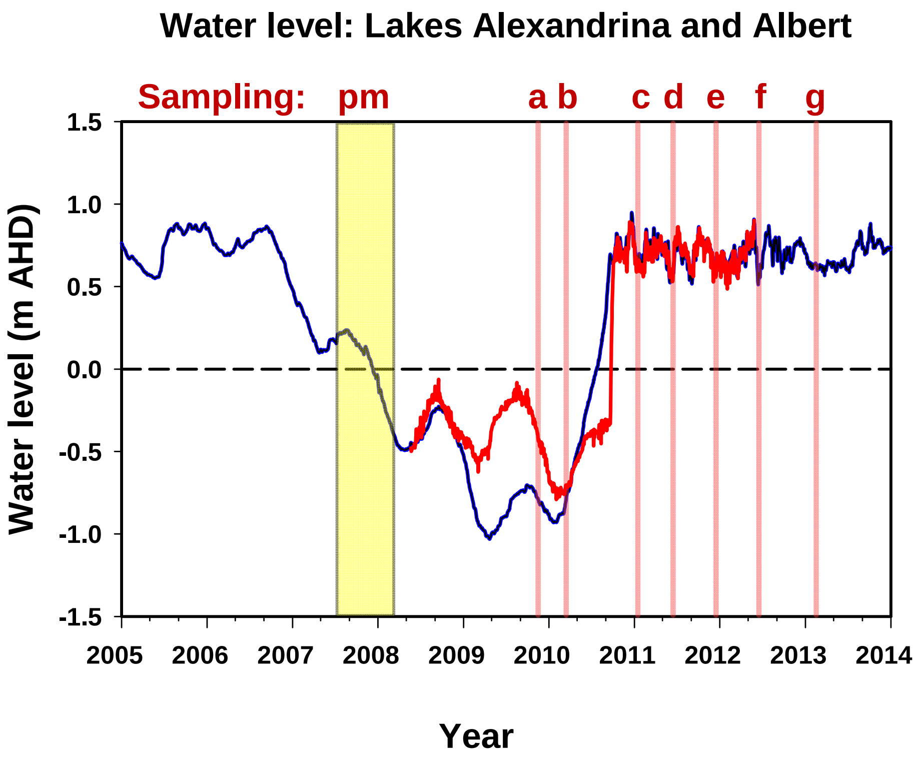


Figure 1-1 Plot of water levels in Lakes Alexandrina (blue line) and Albert (red line) showing when soil monitoring samples were collected. “pm” indicates limited pre-monitoring sampling that was undertaken in 2007 and 2008. Generally, “pm” samples included in this report were collected under subaqueous conditions and the data generated represents the best available pre-drought ASS baseline conditions.

Figure 1-2 Map of the Lower Lakes and adjacent tributaries showing the locations of the 24 study areas.

1.2 Field sampling of soils

Representative study areas were selected around the margins of Lakes Alexandrina and Albert as well as from the tributaries (Finniss River and Currency Creek). Where possible, the sites sampled for this project were positioned within a few metres of former sampling sites that had been established as part of studies of ASS in Lake Alexandrina and Lake Albert (Baker *et al.* 2010; Baker *et al.* 2011; Fitzpatrick *et al.* 2010b; Fitzpatrick *et al.* 2008a; Fitzpatrick *et al.* 2008b; Fitzpatrick *et al.* 2009; Fitzpatrick *et al.* 2008c). Sampling locations and dates are displayed in Table 1-1 and sampling details are presented in Baker *et al.* (2013a), Baker *et al.* (2013b), Baker *et al.* (2011) and Baker *et al.* (2010).

A Global Positioning System (GPS) was used to re-locate sample sites. Soil profile sampling was carried out by observable soil horizon and was achieved using spades and a range of auger types. Sampling was relatively shallow (< 1.0 m) to encompass the materials most likely to be influenced by oxidation.

At each site, GPS co-ordinates and site descriptions were recorded. Grid coordinate locations (WGS84 datum) are presented in Table 1-1. Photographs of the site were taken at photographic points that had been established in previous studies (See Baker *et al.* 2013a; Baker *et al.* 2013b). Approximately four soil cores were collected at each study site. Cores were stored in ice for transportation to the laboratory. In the laboratory, each core was photographed with a length scale and soil horizons were subsampled (See Baker *et al.* 2013a; Baker *et al.* 2013b). Soil material was described and physical properties such as colour, consistency, structure and texture recorded follow McDonald *et al.* (1990) (See Baker *et al.* 2013a; Baker *et al.* 2013b). The presence of ‘sulfidic’ smells (e.g., H_2S – rotten egg gas and methyl thiols) as well as oxidising odours (SO_2) were recorded. Representative sub-samples were placed in plastic jars for acid-base accounting, electrical conductivity and pH measurements. Additional subsamples were collected in chip trays for morphological study and incubation experiments. Analytical methods and data are presented in Baker *et al.* (2013a), Baker *et al.* (2013b), Baker *et al.* (2011) and Baker *et al.* (2010).

For the purposes of this report, selected study sites were examined in detail to assess rates of change and to help explain some of the processes occurring within soil profiles during drought and subsequent inundation. The study sites selected for this overview included only those that were continually monitored between August 2007 and February 2013 and those that were subsequently added to the monitoring program due to evidence of significant acidification hazard (Table 1-1: sites highlighted in grey). Budgetary constraints meant that a number of sites, considered to pose low acidification hazards, were dropped from the monitoring program. For the purposes of this report, data from these sites were not considered.

Table 1-1 Sampling dates and location of soil sampling sites for each monitoring occasion. Eastings and Northings are based on the WGS84 datum, Zone 54H. Note: NS indicates that no sample was collected. Grey shading indicates soil profiles that will be examined in detail as part of this study and were either continuously sampled or were added to the sampling program during the course of the monitoring due to evidence of significant acidification hazard.

Site ID	**Locality**	**Easting**	**Northing**	**Pre Monitoring - pm** (Baker *et al.* 2010)	**Sampling – a** (Baker *et al.* 2010)	**Sampling – b** (Baker *et al.* 2010)	**Sampling – c** (Baker *et al.* 2011)	**Sampling – d** (Baker *et al.* 2011)	**Sampling – e** (Baker *et al.* 2013b)	**Sampling – f** (Baker *et al.* 2013b)	**Sampling – g** (Baker *et al.* 2013a)
LF01-A	Wallys Landing and Wetland	303198	6079714	14/05/2009	4/11/2009	11/03/2010	11/01/2011	08/06/2011	13/12/2011	21/06/2012	07/02/2013
LF01-B		303216	6079636	14/05/2009	4/11/2009	11/03/2010	11/01/2011	08/06/2011	NS	NS	c
LF01-C		303087	6079610	NS	4/11/2009	11/03/2010	14/02/2011	08/06/2011	NS	NS	NS
LF01-D		303081	6079604	NS	4/11/2009	11/03/2010	14/02/2011	08/06/2011	13/12/2011	21/06/2012	NS
LF02-A	Point Sturt North	321247	6070294	15/03/2008	25/11/2009	10/03/2010	18/01/2011	26/05/2011	29/11/2011	15/06/2012	20/02/2013
LF02-B		321290	6070414	15/03/2008	25/11/2009	10/03/2010	18/01/2011	26/05/2011	29/11/2011	15/06/2012	NS
LF02-C		321310	6070444	10/08/2009	25/11/2009	10/03/2010	18/01/2011	26/05/2011	NS	NS	NS
LF02-D		321220	6070249	NS	NS	NS	NS	NS	29/11/2011	15/06/2012	20/02/2013
LF03-A	Milang	316106	6079440	10/08/2007	13/11/2009	10/03/2010	18/01/2011	26/05/2011	06/12/2011	15/06/2012	07/02/2013
LF03-B		316461	6079069	10/08/2007	13/11/2009	10/03/2010	18/01/2011	26/05/2011	06/12/2011	21/06/2012	NS
LF03-C		316558	6078990	10/08/2009	13/11/2009	10/03/2010	18/01/2011	26/05/2011		NS	NS
LF04-A	Tolderol	331889	6083697	10/08/2007	13/11/2009	12/03/2010	14/01/2011	19/05/2011	07/12/2011	21/06/2012	11/02/2013
LF04-B		332006	6083479	10/08/2007	13/11/2009	12/03/2010	14/01/2011	19/05/2011	NS	NS	NS
LF04-C		331944	6083033	10/08/2009	13/11/2009	12/03/2010	14/01/2011	19/05/2011	07/12/2011	18/06/2012	NS
LF05-A	Lake Reserve Road	339392	6089955	10/08/2007	13/11/2009	12/03/2010	19/01/2011	18/05/2011	NS	NS	NS
LF05-B		339455	6089878	10/08/2007	13/11/2009	12/03/2010	19/01/2011	18/05/2011	NS	NS	NS
LF05-C		339455	6089843	NS	13/11/2009	12/03/2010	19/01/2011	18/05/2011	NS	NS	NS
LF06-A	Poltalloch	338984	6070340	4/03/2008	20/11/2009	17/03/2010	24/01/2011	24/05/2011	12/12/2011	18/06/2012	13/02/2013
LF06-B		338876	6070502	NS	20/11/2009	17/03/2010	24/01/2011	24/05/2011	12/12/2011	19/06/2012	NS
LF07-A	Waltowa	352351	6059112	14/02/2008	20/11/2009	1/03/2010	25/01/2011	01/06/2011	05/12/2011	19/06/2012	05/02/2013
LF07-B		352290	6059048	16/10/2008	20/11/2009	1/03/2010	25/01/2011	01/06/2011	05/12/2011	13/06/2012	NS
LF08-A	Meningie	349066	6049328	1/07/2007	20/11/2009	1/03/2010	25/01/2011	01/06/2011	15/12/2011	13/06/2012	05/02/2013
LF08-B		349053	6049398	NS	20/11/2009	1/03/2010	25/01/2011	01/06/2011	15/12/2011	13/06/2012	05/02/2013
LF09-A	Kennedy Bay	343823	6044778	1/07/2007	20/11/2009	1/03/2010	24/01/2011	30/05/2011	NS	NS	NS
LF09-B		343830	6044714	1/07/2007	20/11/2009	1/03/2010	24/01/2011	30/05/2011	NS	NS	NS
LF10-A	Campbell Park	341307	6056483	1/07/2007	15/10/2009	2/03/2010	9/02/2011	31/05/2011	19/12/2011	13/06/2012	13/02/2013
LF10-B		341126	6056569	NS	15/10/2009	2/03/2010	9/02/2011	31/05/2011	NS	NS	NS
LF10-C		341114	6056623	1/07/2007	15/10/2009	2/03/2010	9/02/2011	31/05/2011	19/12/2011	20/06/2012	13/02/2013
LF10-D		341097	6056787	NS	15/10/2009	2/03/2010	9/02/2011	31/05/2011	19/12/2011	20/06/2012	NS
LF10-E		341098	6056901	NS	15/10/2009	2/03/2010	9/02/2011	31/05/2011	NS	NS	NS
LF11-A	The Narrows	335102	6067460	21/02/2008	20/11/2009	17/03/2010	24/01/2011	24/05/2011	NS	NS	NS
LF11-B		335278	6067652	21/02/2008	20/11/2009	17/03/2010	24/01/2011	24/05/2011	NS	NS	NS
LF12-A	Loveday Bay	326796	6061286	NS	25/10/2009	2/03/2010	8/02/2011	30/05/2011	19/12/2011	20/06/2012	NS
LF12-B		326711	6061362	NS	25/10/2009	2/03/2010	8/02/2011	30/05/2011	19/12/2011	13/06/2012	13/02/2013
LF12-C		326420	6061713	NS	25/10/2009	2/03/2010	8/02/2011	30/05/2011	19/12/2011	13/06/2012	13/02/2013
LF12-D		327059	6060960	13/08/2009	NS	2/03/2010	8/02/2011	30/05/2011	NS	NS	NS
LF13-A	Tauwitcherie	319050	6060550	13/02/2008	4/11/2009	3/03/2010	15/02/2011	06/06/2011	13/12/2011	13/06/2012	07/02/2013

Site ID	Locality	Easting	Northing	Pre Monitoring - pm (Baker *et al.* 2010)	Sampling – a (Baker *et al.* 2010)	Sampling – b (Baker *et al.* 2010)	Sampling – c (Baker *et al.* 2011)	Sampling – d (Baker *et al.* 2011)	Sampling – e (Baker *et al.* 2013b)	Sampling – f (Baker *et al.* 2013b)	Sampling – g (Baker *et al.* 2013a)
LF13-B		318997	6060592	NS	4/11/2009	3/03/2010	15/02/2011	06/06/2011	NS	NS	NS
LF14-A	Ewe Island	315510	6062591	13/02/2008	4/11/2009	3/03/2010	15/02/2011	06/06/2011	NS	NS	NS
LF15-A	Boggy Creek	311128	6065875	NS	30/10/2009	3/03/2010	21/02/2011	27/06/2011	NS	NS	NS
LF15-B		311139	6065855	21/07/2009	30/10/2009	3/03/2010	21/02/2011	27/06/2011	16/11/2011	21/06/2012	07/02/2013
LF15-C		311147	6065827	NS	30/10/2009	3/03/2010	21/02/2011	27/06/2011	16/11/2011	14/06/2012	NS
LF16-A	Clayton	312384	6069230	24/08/2007	13/11/2009	3/03/2010	2/02/2011	07/06/2011	NS	NS	NS
LF16-B		312402	6069239	24/08/2007	13/11/2009	3/03/2010	14/02/2011	07/06/2011	NS	NS	NS
LF17-A	Point Sturt South	314849	6069780	NS	30/10/2009	11/03/2010	02/02/2011	07/06/2011	06/12/2011	14/06/2012	20/02/2013
LF17-B		314806	6069675	21/07/2009	30/10/2009	11/03/2010	02/02/2011	07/06/2011	06/12/2011	15/06/2012	20/02/2013
LF17-C		314770	6069615	NS	30/10/2009	11/03/2010	02/02/2011	07/06/2011	NS	NS	NS
LF17-D		314757	6069579	NS	30/10/2009	11/03/2010	NS	NS	NS	NS	NS
LF18-A	Browns Beach	350089	6053293	17/10/2008	20/11/2009	1/03/2010	25/01/2011	01/06/2011	NS	NS	NS
LF18-B		350028	6053310	NS	20/11/2009	1/03/2010	25/01/2011	01/06/2011	NS	NS	NS
LF18-C		350085	6053821	17/10/2008	20/11/2009	1/03/2010	25/01/2011	01/06/2011	NS	NS	NS
LF19-A	Dog Lake	332033	6086787	NS	NS	NS	19/01/2011	19/05/2011	07/12/2011	15/06/2012	18/02/2013
LF19-B		331011	6085785	NS	NS	NS	NS	NS	07/12/2011	18/06/2012	18/02/2013
LF20-A	Boggy Lake	335054	6089352	NS	NS	NS	19/01/2011	18/05/2011	07/12/2011	18/06/2012	18/02/2013
LF20-B		334841	6090032	NS	NS	NS	NS	NS	07/12/2011	18/06/2012	18/02/2013
LF21-A	Windmill Site	345597	6064184	NS	NS	NS	9/02/2011	31/05/2011	12/12/2011	18/06/2012	13/02/2013
LF21-B		345519	6064056	NS	NS	NS	9/02/2011	31/05/2011	12/12/2011	19/06/2012	NS
LF22-A	Goolwa Channel	302272	6070678	NS	NS	NS	21/01/2011	25/05/2011	NS	NS	NS
LF23-A	Lower Currency	301055	6072892	NS	NS	NS	21/01/2011	25/05/2011	14/12/2011	19/06/2012	11/02/2013
LF24-A	Lower Finniss	305780	6073929	NS	NS	NS	14/02/2011	08/06/2011	14/12/2011	14/06/2012	11/02/2013
LF24-B		305780	6073929	NS	NS	NS	14/02/2011	08/06/2011	14/12/2011	14/06/2012	NS

2. OVERVIEW OF DATA

The following section is designed to provide an overview of changes that occurred within soil profiles before, during and after the drought broke. Soil characteristics/variables that will be examined in detail include soil pH (pH_w), incubation pH (pH_{inc}), peroxide pH after hydrogen peroxide treatment (pH_{OX}), Chromium-Reducible Sulfur (CRS), Titratable Actual Acidity (TAA), Retained Acidity (RA), Acid Neutralisation Capacity (ANC) and Net Acidity (NA). A summary of these terms is presented in Table 2-1. One of the problems with current methodology has been highlighted for these soils which are in a transition of recovery: field observations indicate high spatial heterogeneity during recovery with both sulfidic patches and jarositic remnants, therefore, the soil at a local scale is in a state of extreme disequilibrium. The determination of whether to analyse ANC and RA is dependent on soil pH (< 4.5 for RA; > 6.5 for ANC), so that these phases may be present but not measured in the standard protocol. This may be a problem in a few specific samples and responsible for discrepancies between e.g. net acidity and incubation pH.

Table 2-1. Explanation of acid sulfate soil terms and abbreviations that will be discussed in detail throughout this report

Variable	Abbreviation	Explanation
Soil pH	pH_w	Soil is mixed with deionised water at a 1:1 (v:v) ratio, allowed to equilibrate for a short period of time, and pH is then measured.
Incubation pH	pH_{inc}	Soil is kept moist and sulfide minerals are allowed to oxidise for a period of more than ten weeks, and pH is then measured.
pH testing after peroxide treatment	pH_{OX}	Soil is oxidised using hydrogen peroxide, and pH is then measured. Is supposed to represent the worst-case oxidation scenario.
Chromium-reducible sulfur	CRS	Sulfide measured by iodometric titration after acidic chromous chloride reduction.
Titratable Actual Acidity	TAA	Acidity titration to pH 6.5 with standardised NaOH on 1:40, suspension in 1 M potassium chloride.
Retained Acidity	RA	The ‘less available’ fraction of the existing acidity (not measured by TAA) that may be released slowly into the environment by hydrolysis of relatively insoluble sulfate salts (e.g. jarosite and natrojarosite).
Acid Neutralisation Capacity	ANC	Measurement of a soil’s ability to neutralise or buffer added acid and conventionally expressed as equivalent $CaCO_3$.
Net Acidity	NA	Soil acidity calculated as: Net Acidity = potential sulfuric acidity + existing acidity - (acid neutralising capacity/fineness factor).
Specific Electrical Conductance	SEC	measure of the capacity of water (or other media) to conduct an electrical current.

These data will be presented in a number of ways to best explain the spatial and temporal variations that occurred within soil profiles during the monitoring period. An overview of all the data collected during the monitoring period will be presented on boxplots and cumulative probability plots. Stacked vertical bar plots overlain on location maps will be used to explain changes to soil characteristics that relate to spatial distribution around the lakes, depth within the soil profile and water level change through the course of the drought and subsequent inundation.

2.1 Statistical and graphical rationale

Statistical methods provide valuable tools for describing geochemical data and have been applied widely. Statistical-summary data (medians, means, standard deviations, quantiles, ranges) can provide useful information, but several inherent pitfalls apply with geochemical data. Firstly, datasets frequently contain a high proportion of non-detects for many trace elements which precludes the calculation of reliable mean values. As a result, medians are often preferred as indicators of central tendency, and it is more robust and less affected by outlying data. Secondly, many data populations do not have normal or log-normal distributions and it is recognised that outliers in these populations can produce spuriously large ranges.

In most natural systems geochemical distributions are generally polymodal and are usually skewed (Reimann and Filzmoser 2000; Shand *et al.* 2007). The traditional assumption that geochemical datasets are either normal, or more generally, lognormal (Ahrens 1954) limits the application of many traditional statistical tests. Ideally, non-parametric statistical tools should be engaged to account for the non-normal distributions of geochemical data since they are not based on model assumptions. Hence, simple maxima, minima and means are often not the best ways of assessing geochemical data.

Box plots, histograms and cumulative-frequency (or cumulative-probability) diagrams have also proved useful in characterising chemical data distributions. They are also readily available in many statistical plotting packages. Box plots (Tukey 1977) can be useful indicators of baseline ranges as they show graphically the data ranges of a population based on percentiles and can also highlight outliers (Figure 2-1). Here, the upper and lower hinges (margins) of the box are defined as the 25th and 75th percentiles displaying the inter-quartile range (i.e. 50% of the data) and the whiskers usually denote the 10th and 90th percentiles (lowest and highest data points that lie within the range defined as 1.5 times the inter-quartile range). Outliers beyond this range can be denoted by separate symbols. The box plot represents a relatively robust approach to data assessment as it makes no prior assumptions about the data distribution. Reimann *et al.* (2005) concluded that box plots were the most useful statistical tools for assessing baseline (or background) concentrations provided that outliers comprised less than 15% of the dataset.

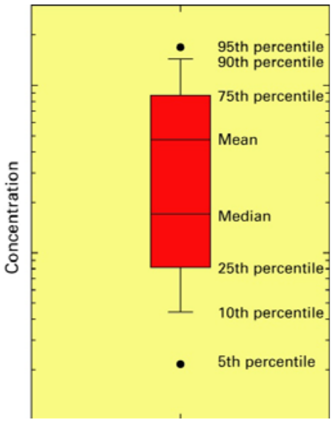


Figure 2-1. Box plot showing how data are plotted on a percentile basis (From Shand *et al.* 2007).

The use of cumulative-probability diagrams has been promoted as a succinct means of identifying distinct populations in groundwater datasets (Runnells *et al.* 1998). They have also been used extensively in the mineral exploration industry to define anomalous concentrations. Cumulative-frequency diagrams and cumulative-probability diagrams are similar except that the y-axis is defined differently. The cumulative frequency represents the cumulative number of observations for each value in the observed range. Each point on the frequency curve represents the total number of samples for all values less than or equal to the current value. The cumulative-probability distribution merely normalises the frequency values by the number of samples in the dataset so that they sum to 1 (or 100%). The cumulative probability plot is preferable as it spreads out the data at the extremes, which are often the areas of greatest interest (Reimann *et al.* 2005).

If the concentration (x-axis) scale in a probability plot is logarithmic, a log-normal distribution will plot as a straight line while a bimodal or multimodal distribution will be curved (Sinclair 1974). This relationship can be used to identify pollutants for example, because these are subject to different processes or sources and hence may form data populations which are distinct from those derived by natural processes. Hence in cumulative-probability plots, maximum flexure may be used to discriminate baseline chemistry from pollution-impacted compositions. Care must be taken with their interpretation however, as data ranges for baseline populations can overlap with polluted populations and there are several types of natural biogeochemical reaction that can alter data distributions by removing or limiting concentrations in solution (Figure 2-2): these include redox reactions, adsorption reactions and mineral-solubility controls. For those samples with a determinand below detection limit, if a zero value is assigned the data will not plot using a log scale (see ‘below analytical detection limit’ in Figure 2-2).

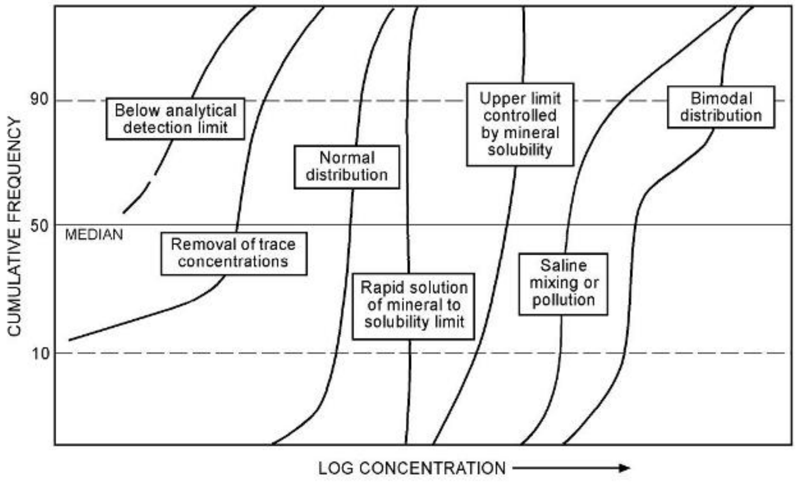


Figure 2-2. Cumulative probability plot highlighting potential hydrochemical distributions controlled by geochemical processes. These plots can be also useful for determining different populations and geochemical processes in soils (From Shand *et al.* 2007).

In order to use statistical methods, it is important to have representative samples of the system as well as a large number of samples. The characterisation of soils, especially sub-aqueous soils is difficult to establish for a number of reasons: sampling is often biased towards easiest access to sites and the ease of access (e.g. wetland margins), samples may be limited to specific (shallow) horizons, and the sample may undergo chemical changes during and after sampling. Although statistical methods are widely used to assess geochemical parameters, they can and should not be used in isolation and a basic understanding and investigation of the underlying processes controlling soil and water chemistry and chemical variation is required (Shand *et al.* 2007).

2.2 Soil pH (pH_w)

The pH_w data for the monitoring period are shown on a boxplot and cumulative probability plot in Figure 2-3. Data for a number of sites collected in 2007 (pm data) are shown for comparison. Although these do not directly correspond with the monitored samples, they are the only existing baseline data on ASS from the period before significant drying and considered representative for some parameters. Only 3 sites (15 samples) from the pre-monitoring period were monitored for the full time period. Although the pm data (9 sites, 54 samples) may be considered as a pre-drying baseline, care should be taken not to correlate directly with the later monitored data, especially for concentration data.

The pm data show a narrow range of pH_w values and are mostly circumneutral. A few samples have lower pH but it is likely that these samples (mainly from deeper in the profile) partially oxidised prior to measurement. The median pH_w fell to a low value during the drought (sampling a) as the soils oxidised to around pH_w 4, and displayed a much larger range (Figure 2-3). The average and interquartile ranges of pH_w fell slightly during the second drought period sampling (sampling b). Following the large surface inflows to the lakes as the drought broke, there was a significant increase in pH_w: the median pH_w increased to pH_w 6.9, however, the range in pH_w remained high as many samples remained acidic. There was little change in median and the range for the duration of the sampling period. The median and interquartile ranges had a tendency for higher values during summer periods (samplings c, e and g) and lower for winter (d and f) but it is not clear if this is a seasonal trend (e.g. caused by temperature and microbial activity).

The partial recovery is also evident on the cumulative probability plots (Figure 2-3), where a large proportion of samples remained acidic, despite a relatively rapid change in the median. There has, therefore, not been a gradual recovery of these samples, which is consistent with a strong acid buffering in many of the soil materials.

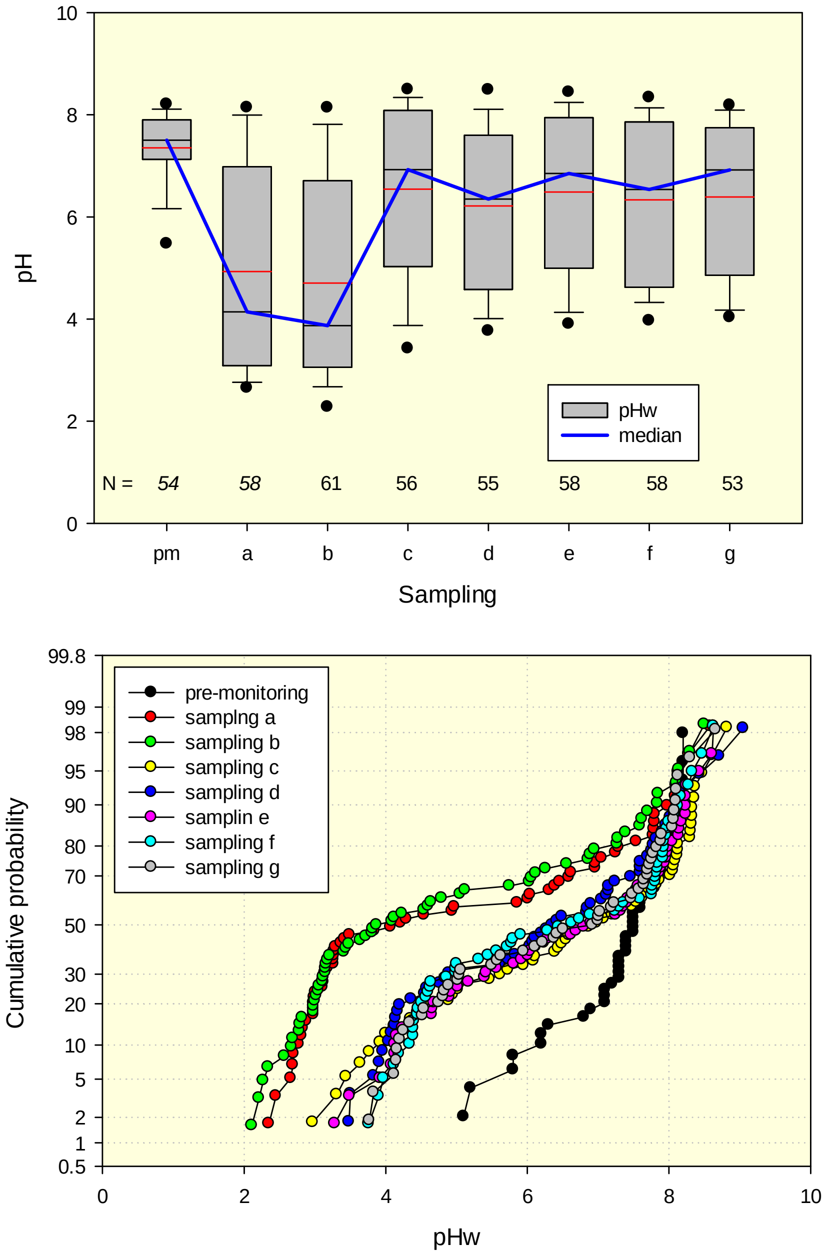
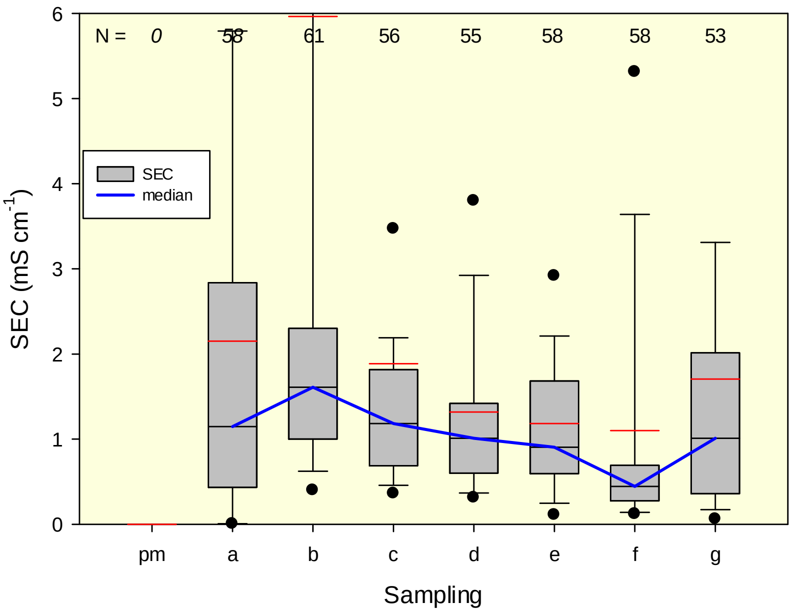


Figure 2-3 Boxplot (top) showing pH_w for samplings a to g and data from 2007 (pm). Median is shown as black horizontal line and mean as horizontal red line. The same data are shown on a cumulative probability plot (bottom).

2.3 Specific Electrical Conductance (SEC)

The range and median specific electrical conductance (SEC) were highest during the drought period. There was a general decreasing trend over time up to sampling f, followed by an increase in sampling g. This follows the same general trend as surface water SEC (www.epa.sa.gov.au). The earlier data display a linear trend (log-normal distribution), but the latter samplings (f and g) indicate two separate populations, likely as a consequence of freshening of the soil porewaters, particularly in the sandy soils.



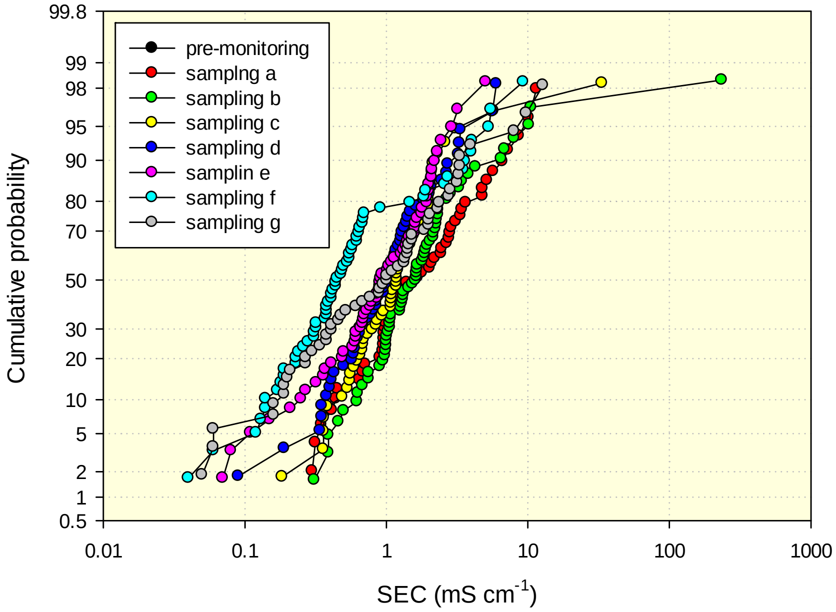
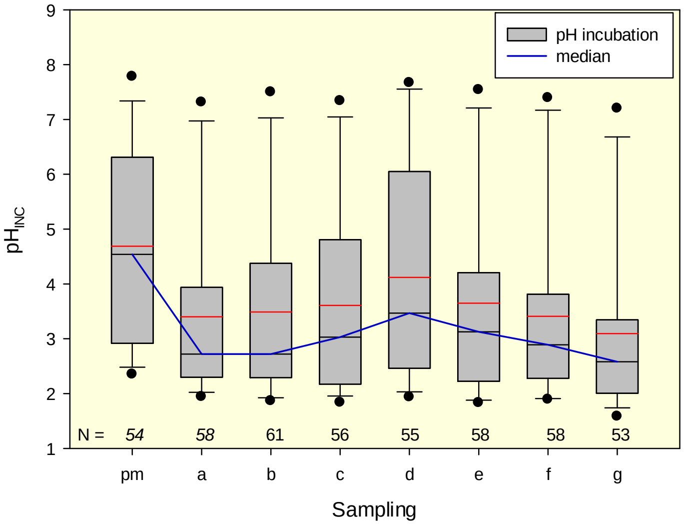


Figure 2-4 Boxplot (top) showing SEC for samplings a to f. Median is shown as black horizontal line and mean as horizontal red line. The same data are shown on a cumulative probability plot (bottom).

2.4 Incubation pH (pH_{inc})

pH incubation (pH_{inc}) experiments involved keeping laboratory samples moist for a specified period (> 10 week), thus allowing a relatively realistic oxidation of sulfide minerals to occur. The resultant drop in pH was measured and used to infer potential impacts of oxidation caused by drought conditions in the Lower Lakes.

The monitoring data showed a slight increase in median pH_{inc} and upper quartile incubations following the end of drought, but this decreased again up to sampling g (Figure 2-5). This was also accompanied by a decrease in the interquartile range. This may be related to alkalinity generation followed by consumption with existing acidity and will be discussed in later chapters.



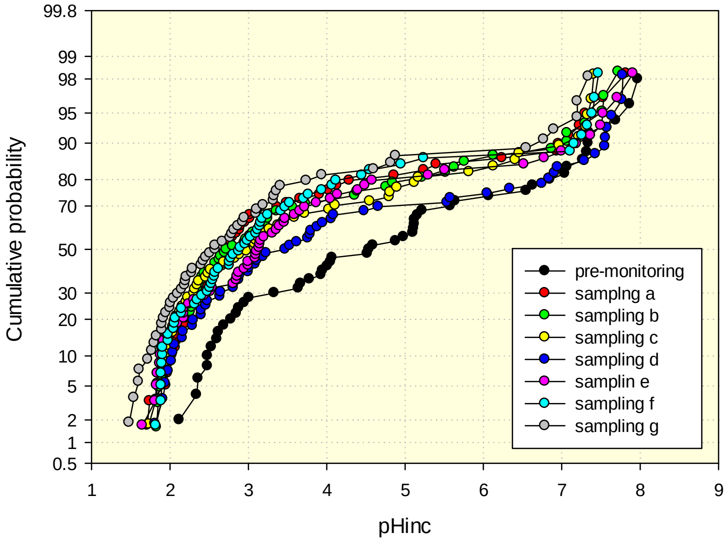


Figure 2-5 Boxplot (top) showing incubation pH_{inc} for samplings a to g and data from 2007 (pm). Median is shown as black horizontal line and mean as horizontal red line. The same data are shown on a cumulative probability plot (bottom).

A significant number (10-20 %) showed little tendency to acidify below pH 7 as shown on the cumulative probability plot (Figure 2-5), probably due to high ANC in these soils. Nevertheless, the data show that there is little change in the overall potential of soils to acidify despite a partial recovery in pH_w (Figure 2-3).

2.5 Chromium Reducible Sulfur (CRS)

The lowest median concentrations of CRS (Figure 2-6) were present during the period of low lake levels, consistent with oxidation of sulfide acidity.

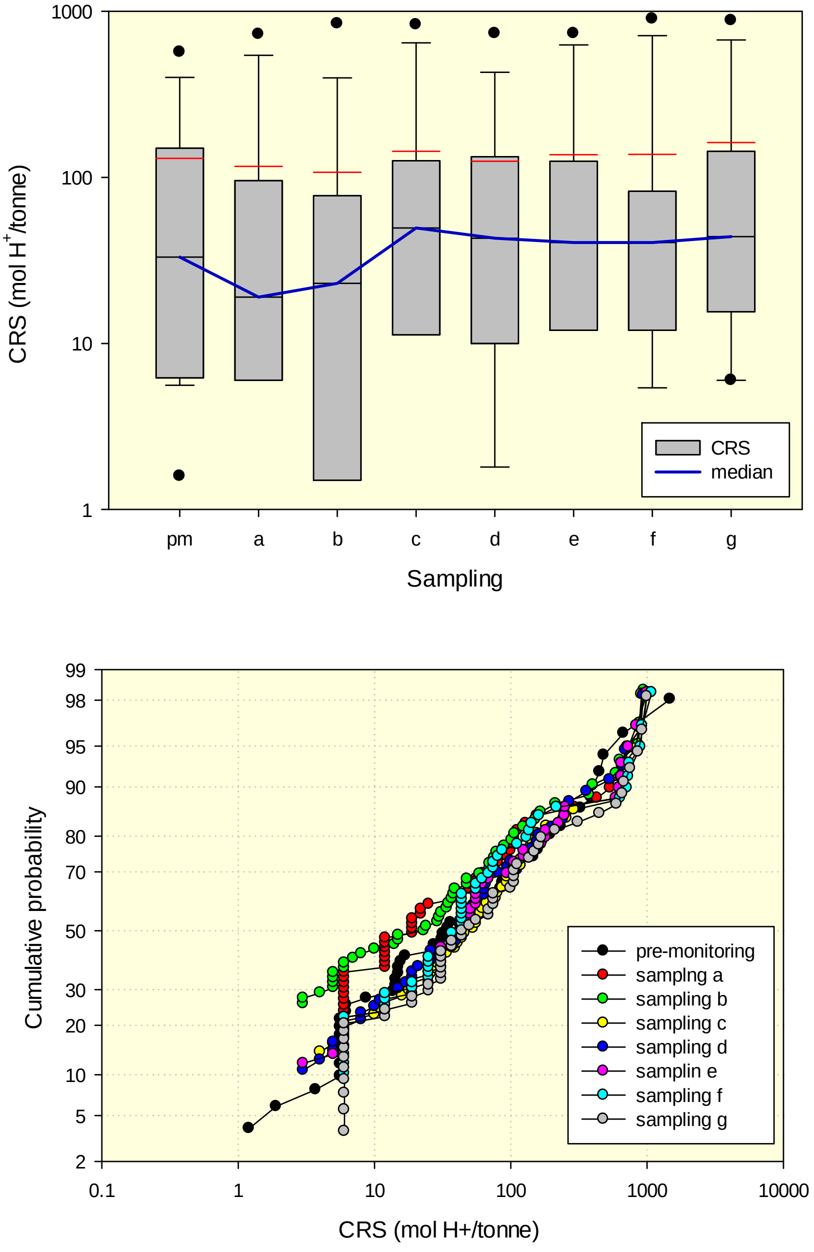


Figure 2-6 Boxplot (top) showing Cr-reducible sulfur (CRS) for samplings a to g and data from 2007 (pm). Median is shown as black horizontal line and mean as horizontal red line. The same data are shown on a cumulative probability plot (bottom).

The median and interquartiles increased by sampling c when water levels were higher. The data thus show that sulfide formation has been significant at a number of sites following inundation of the soils.

2.6 Titratable Actual Acidity (TAA)

TAA was present at low concentrations in only 20 % of the pm samples, and even then is likely to have been generated during the sampling and analytical period. During the drought-impacted low water levels, this rose to more than 50 % of samples, reaching moderate to high concentrations (Figure 2-7).

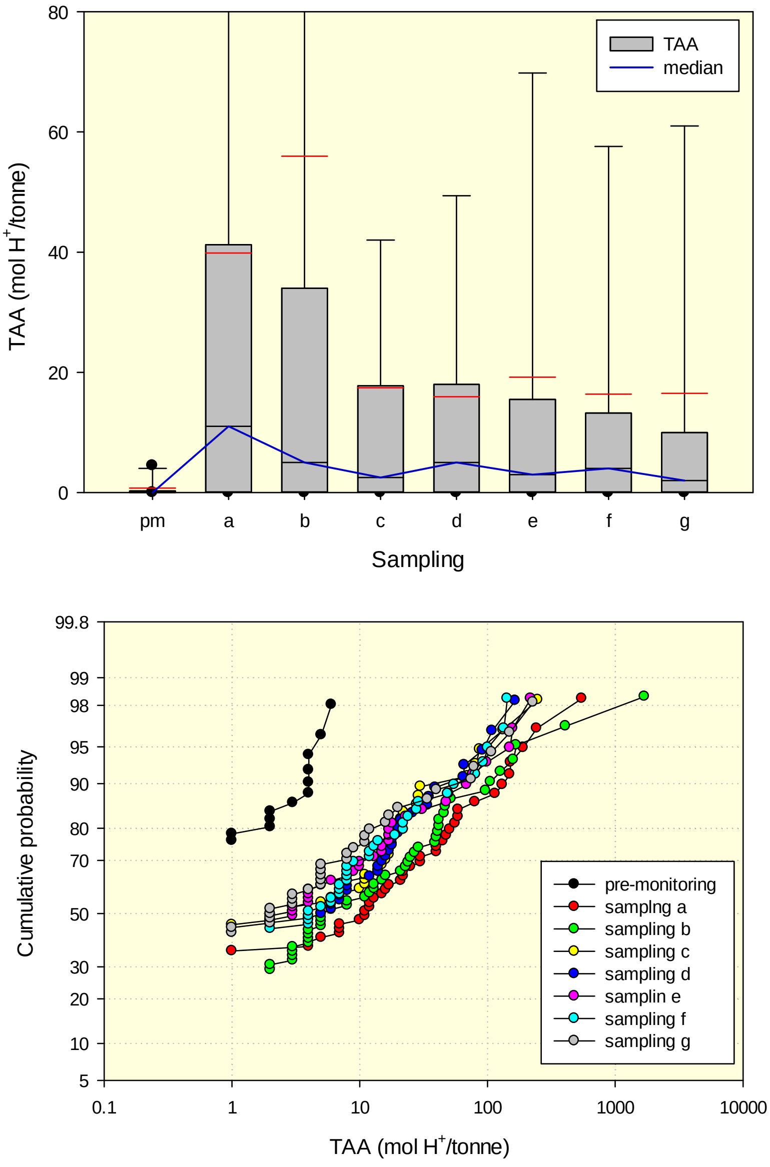


Figure 2-7 Boxplot (top) showing titratable actual acidity (TAA) for samplings a to g and data from 2007 (pm). Median is shown as black horizontal line and mean as horizontal red line. The same data are shown on a cumulative probability plot (bottom).

The median and upper quartile range decreased significantly post-drought, but most samples retained TAA up to sampling g, with TAA not being neutralised or continuously generated due to jarosite dissolution.

2.7 Retained Acidity (RA)

Retained Acidity (RA) was not present in any of the pm samples prior to oxidation. RA is normally a reflection of secondary oxyhydroxide minerals such as jarosite. Only about 10-20 % of samples contained RA, but some of these were very high (> 100 mol H^+/t). The number of samples with RA decreased with time but some samples (ca. 8 %) still contained some RA by sampling g.

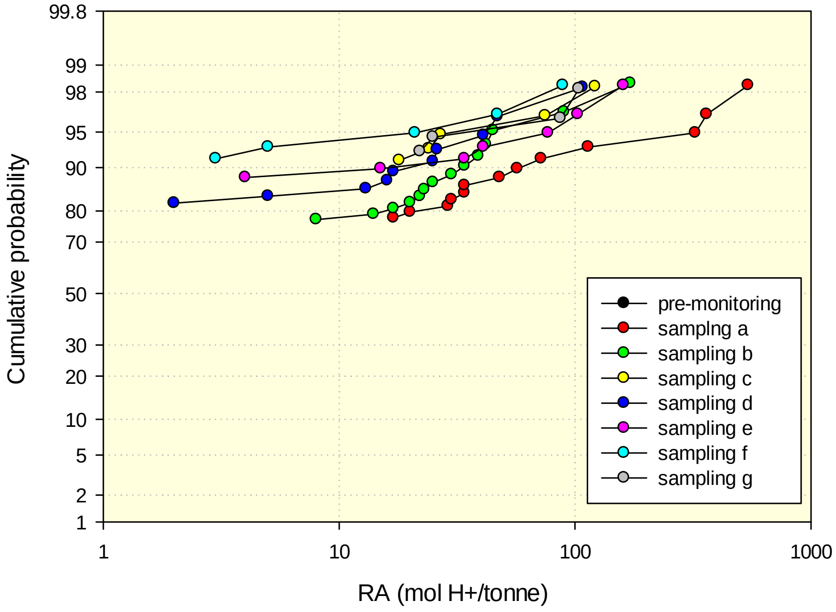


Figure 2-8. Cumulative probability plot for Retained Acidity (RA). RA was not present in any pm samples.

2.8 Acid Neutralising Capacity (ANC)

Acid Neutralising Capacity (ANC) is shown on Figure 2-9. The pm data show that ca. 80 % of samples contained ANC, but this was much lower during the dry period where only about 20 % of samples had measurable ANC. There would appear to be no clear discernible trend in ANC at this scale, and it would appear that ANC has been lost from the system.

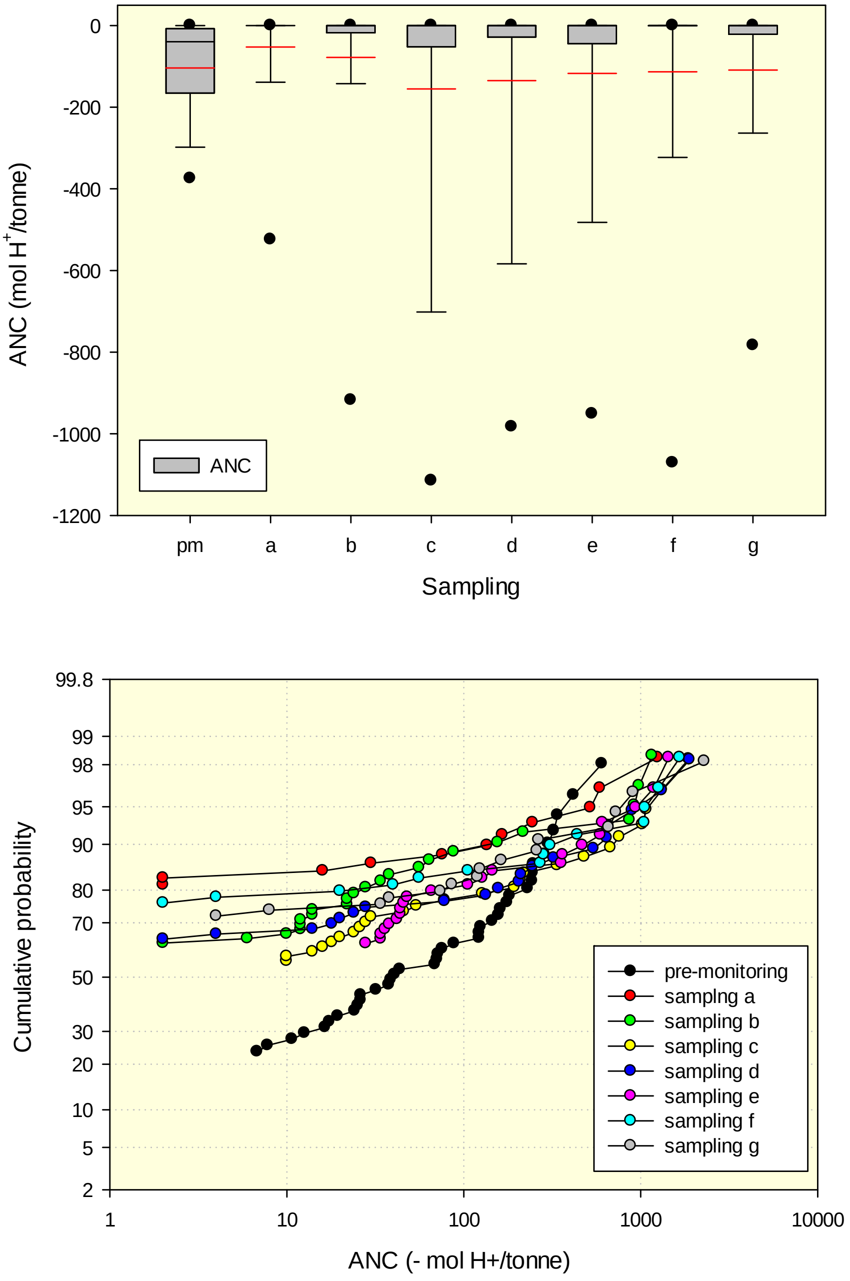


Figure 2-9 Boxplot (top) showing acid neutralising capacity (ANC) for samplings a to g and data from 2007 (pm). Median is shown as black horizontal line and mean as horizontal red line. The same data are shown on a cumulative probability plot (bottom).

2.9 Net Acidity (NA)

The data for Net Acidity (NA) show that there has been a relatively flat trend with time (Figure 2-10), suggesting that the system has not changed in terms of overall hazard potential, although some transport may have occurred locally at the site scale (see later chapters). This is consistent with the incubation pH data which suggest that the degree of hazard and risk has not been removed despite an apparent partial recovery of soil pH_w.

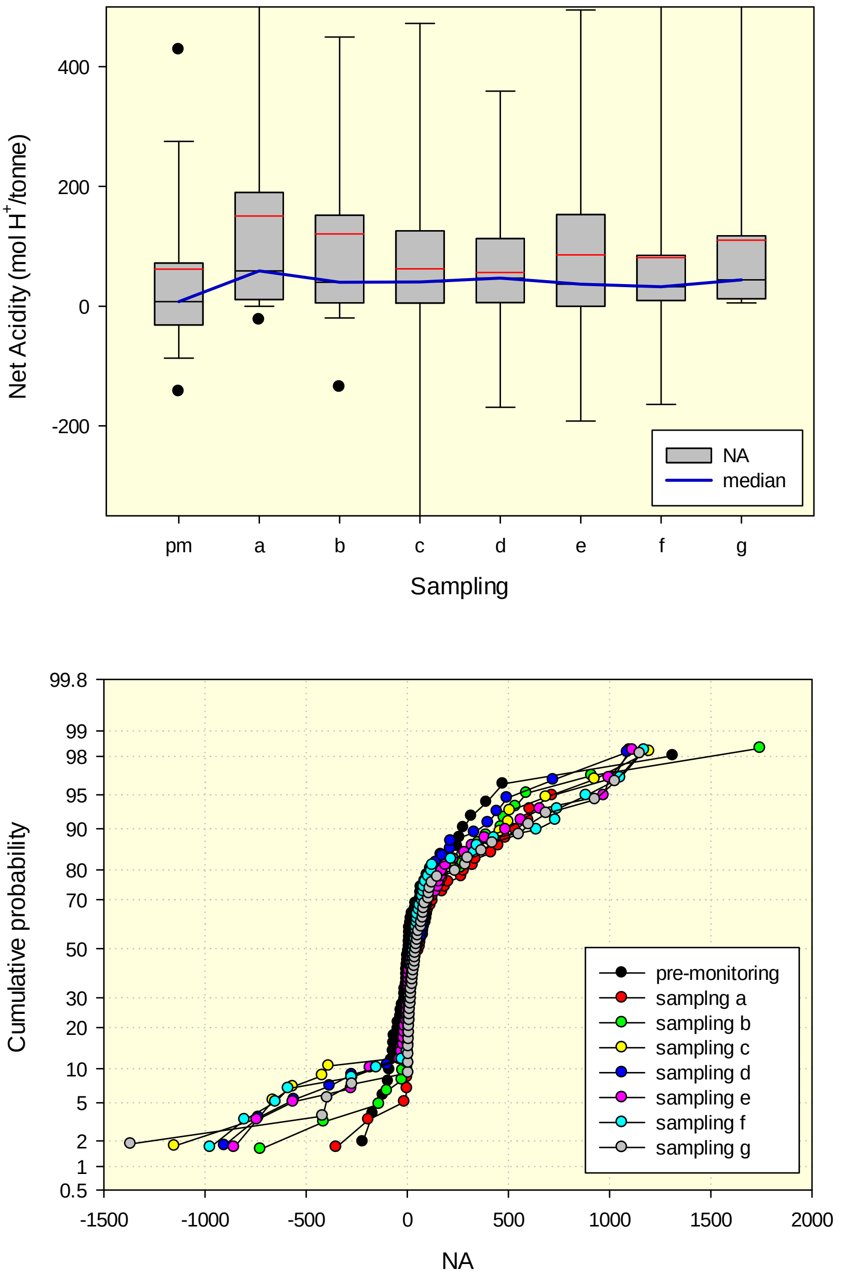


Figure 2-10 Boxplot (top) showing net acidity (NA) for samplings a to g and data from 2007 (pm). Median is shown as black horizontal line and mean as horizontal red line. The same data are shown on a cumulative probability plot (bottom).

3. SPATIAL AND TEMPORAL VARIATIONS

The following section examines the changes to soil characteristics that relate to spatial distribution around the Lower Lakes, depth within the soil profile and water level changes through the course of the drought and subsequent inundation. Soil characteristics that are considered include changes to pH (pH_w), incubation pH (pH_{inc}), Chromium-Reducible Sulfur (CRS), Titratable Actual Acidity (TAA), Retained Acidity (RA), Acid Neutralisation Capacity (ANC) and Net Acidity (NA).

For the purposes of this report, selected study sites were examined more closely to help explain changes with time and some of the processes that occurred within soil profiles during drought and subsequent inundation. The study sites selected included those that were continually monitored between August 2007 and February 2013 and those that were subsequently added to the monitoring program due to evidence of significant acidification hazard (Table 1-1: sites highlighted in grey).

Soil monitoring data were collected at each study site on a maximum of eight occasions (Table 1-1 and Figure 1-1). Sampling was carried out according to soil horizon and not by fixed depth interval. Thus, heterogeneity and temporal changes to soil profiles (i.e. colour/redox state) at each study site meant that sampling depths varied during the monitoring period. To facilitate a better understanding of the changes that occurred within soil profiles, the morphological descriptions were examined for each sampling period and soil layers were correlated through time. Soil layers were assigned true depths within the soil profile based on colour, texture, structure and chemistry. This meant that it was possible to recognise changes in soil characteristics such as pH and forms of soil acidity before, during and after the drought broke. To further simplify the dataset and allow more useful interpretation, selected soil horizons were categorised into surface, middle and bottom layers.

Additional supporting data for each of the selected sites is presented in Appendix A. This includes:

- Plots of soil characteristics from all soil layers sampled.
- Summaries of acidification potential, ASS material classification and acidification hazard.
- Summaries of temporal changes (including site photographs) that occurred at each site.

3.1 Data management and graphical rationale

To better display the large amounts of data and communicate the complexity associated with changes in ASS conditions around the Lower Lakes, we have used a number of graphical methods that include stacked and unstacked vertical bar charts displayed spatially on locality maps.

Vertical bar charts provide an easy visual means of displaying multiple component data sets e.g. changes with time. The bar heights are proportional to the values that they represent. With several parameters, the bars can be stacked, thus permitting visualisation of multiple variables. A useful variation is also to normalise the data to 100 % so that changes in each variable can be compared; this is particularly useful where the range of absolute values are large (e.g. transformations in acid pools or solid phase speciation are of interest, Shand *et al.* 2012).

Examples of vertical bar charts and a normalised stacked bar chart (used throughout this report), are shown in Figure 3-1. Variables are plotted on the Y axis versus time, represented as samplings on the X axis. Generally, eight bars are present on each plot, representing the pre-monitoring (pm) sampling and the seven subsequent samplings (a to g). Where bars are absent for particular samplings, soil layers were not present or not able to be adequately identified. Bar colours represent arbitrarily defined value ranges for each plot type. Acidity types, normalised to 100%, are also shown on Figure 3-1.

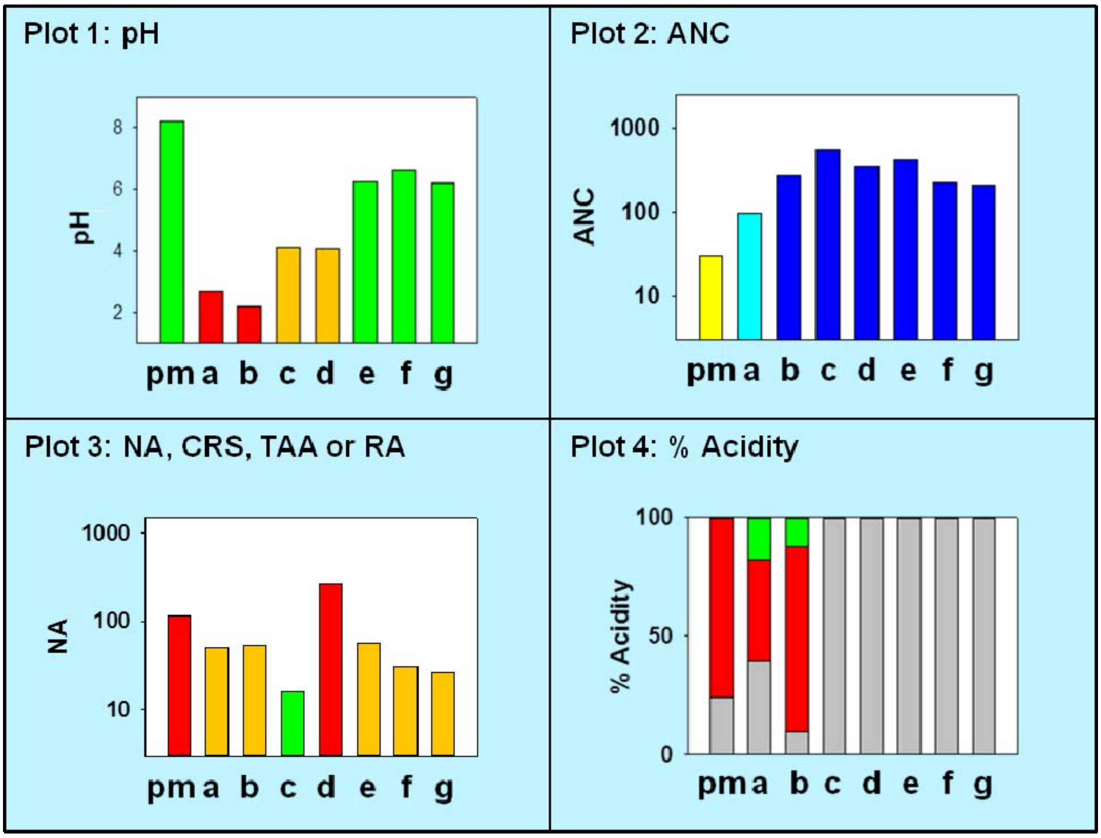


Figure 3-1. Examples of vertical bar charts and a normalised stacked bar chart that will appear throughout this report. (Plot 1) pH values below 4 are shown in red, values between 4 and 5.5 are shown in orange and values above 5.5 are shown in green. (Plot 2 - log scale) ANC values below 28.5 mol H^+/t are shown in yellow, values between 28.5 and 150 mol H^+/t are shown in cyan and values above 150 mol H^+/t are shown in blue. (Plot 3 - log scale) NA, CRS, TAA or RA values below 19 mol H^+/t are shown in green, values between 19 and 100 mol H^+/t are shown in orange and values above 100 mol H^+/t are shown in red. (Plot 4) acidity types, normalised to 100%, are shown on plot 4. Grey represents the chromium-reducible sulfur (CRS) fraction, red represents the Titratable Actual Acidity (TAA) fraction and green represents the Retained Acidity (RA) fraction within each soil layer.

This study combines base maps with vertical bar charts and normalised stacked bar charts to display temporal changes across the Lower Lakes and provide a way to display a wide range of parameters on a single diagram. Figure 3-2 provides an example of sediment pH measurements as a function of time/sampling from various study areas around the Lower Lakes. As discussed in Figure 3-1, each plot displayed on the locality map comprises up to eight vertical bars coloured red, orange, or green. These bars represent soil pH conditions in sediments for each of the eight sampling occasions between August 2007 and February 2013. The use of colour to represent pH ranges enables the rapid assessment of pH trends through time. By presenting the plots on a base map, hot spots and outliers can be easily identified and related to geography and depth within the soil profile.

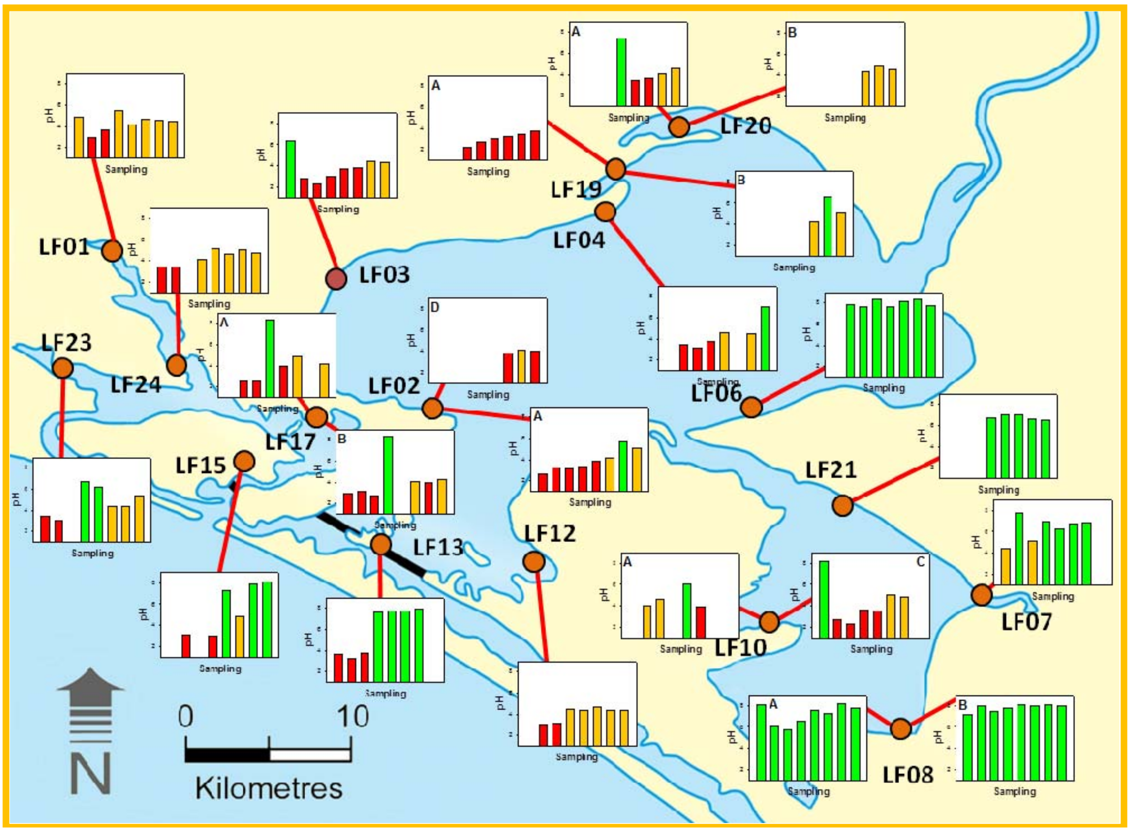


Figure 3-2. Example of vertical bar charts (pH_w) displayed on a locality map (Lower Lakes). Bars represent soil pH conditions in sediments (red: pH < 4, orange: pH 4 to 5.5, green: pH > 5.5) for each of the eight sampling occasions between August 2007 and February 2013. Where bars are absent for particular samplings, soil layers were not present or not able to be adequately identified. Where two plots are associated with a study area, these represent data from proximal soil profiles that are situated along a single transect. The scale on the Y-axis of all pH plots is from 1 to 9.

3.2 Soil texture

Soil texture is an important control on the spatial variability of soil chemistry in the Lower Lakes. Soil type/texture often dictates not only acid generating potential but the longevity and severity of impacts, caused by soil acidification, to human health, biota and water quality.

The importance of soil texture has been long recognised in the ASS community. In fact, environmental management of ASS materials is dependent on both soil texture and acid content (Table 3-1). Coarse ASS materials such as sands and loamy sands require management at far lower acid contents than the equivalent sandy loam or clay.

Table 3-1. Criteria indicating the need for an ASS management plan based on texture range and chromium reducible sulfur concentration and amount of soil material disturbed (Dear *et al.* 2002).

Texture range	**Existing + Potential Acidity** TAA + S_{CR} **Equivalent sulfur (%S) (oven-dry basis)**	
	<1000 t disturbed soil	**>1000 t disturbed soil**
Coarse: Sands to loamy sands	0.03	0.03
Medium: Sandy loams to light clays	0.06	0.03
Fine: Medium to heavy clays	0.10	0.03

A relatively pure sand may contain very low levels of acid generating potential (e.g. < 20 mol H^+/t) but pose a significant risk to human health and biota. Sands are often associated with low levels of ANC (buffering capacity) and can rapidly dry and oxidise under drought conditions. This means that the relatively low levels of acidity contained within the sand can cause rapid pH drops and the formation of acidic mineral efflorescences (e.g. sideronatrite) (Fitzpatrick *et al.* 2010a). These low pH conditions and acidic minerals can pose a relatively short lived risk to human health (airborne dust/direct contact with low pH materials causing eye and skin irritation) and soil biota. Post drought inundation and even rainfall events are often sufficient to dilute and flush these relatively low levels of acidity from exposed near surface sandy sediments.

In contrast, subaqueous clay soils often contain far greater stores of potential acidity in the form of reduced sulfide (pyrite). However, in the Lower Lakes, these soils are also often associated with significant quantities of ANC, are deeper in the profile and tend to take far longer to dry out (i.e. causing oxidation and acidification) under drought conditions. Although clay rich soils may take longer to acidify during drought conditions, following inundation they are also likely to recover more slowly. Additionally, the significant stores of acidity contained within the clay rich sediments can be released over prolonged periods of time to impact on water quality.

Hence, to aid future chemical data discussion and interpretation, a map has been created that summarises the soil textures encountered at selected study sites from around the Lower Lakes (Figure 3-3). At each site, three stacked cells represent soil texture in the top (< 20 cm), middle (30 to 50 cm) and bottom (> 60 cm) of the soil profile. Textures have been separated into three broad categories that comprise peat (green), sand (yellow) and clay (grey). These soil layers/textures correspond to the samples (i.e. and associated data) discussed throughout the remainder of this report.

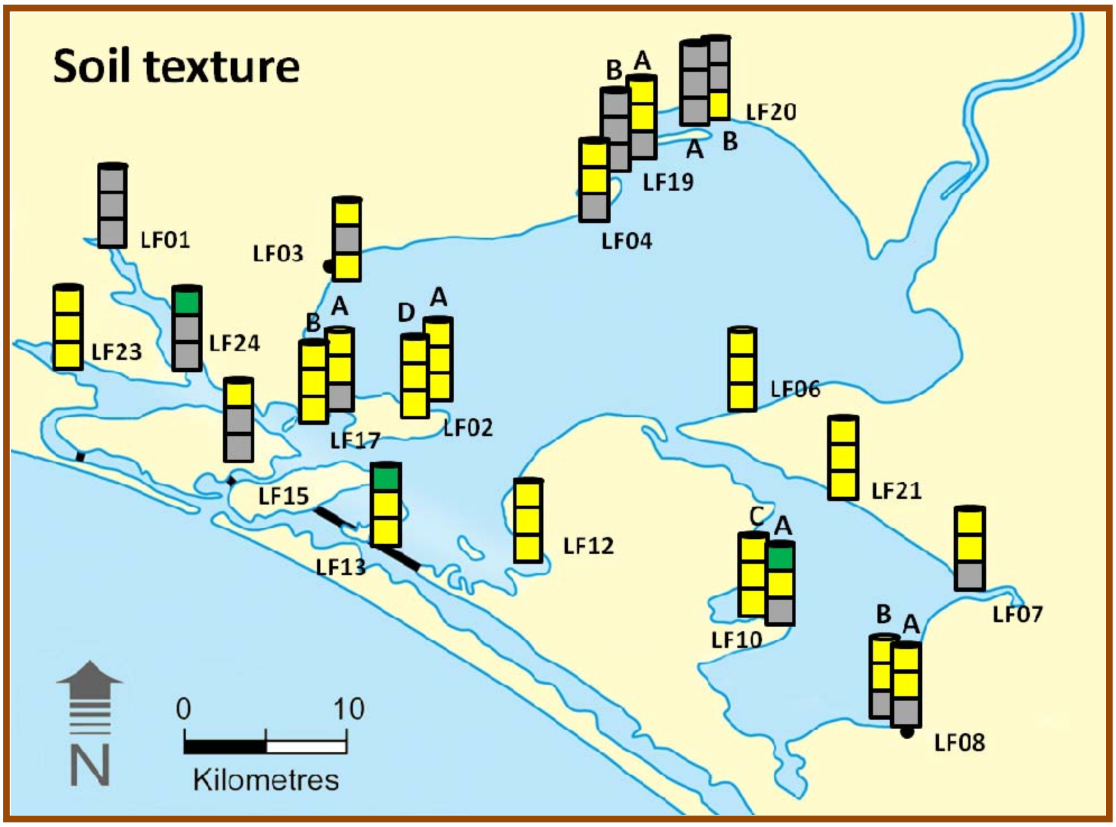


Figure 3-3. Soil texture of sediments in from around the Lower Lakes. Each plot comprises three stacked cells that represent soil texture in the top (< 20 cm), middle (30 to 50 cm) and bottom (> 60 cm) of the soil profile (Green = peat, yellow = sand , grey = clay).

3.3 Soil pH

Overview

Soil pH conditions were highly variable during and after the drought and varied with locality, soil texture and depth within the profile. In **surface** sediments, lowering water levels and resultant oxidation of sulfides caused the original circumneutral soil pH to drop to less than pH 4 (sulfuric) at many locations around the Lower Lakes (Figure 3-4). At Wallys Landing and Wetland (LF01), Poltalloch Station (LF06) and Meningie (LF08) surface sediment pH conditions remained above 5.5. Generally, soil pH rose rapidly (< 10 months), in acidified surface sediments following post drought inundation. However, at some sites, including Dog Lake (LF19-A) and Point Sturt (LF17-B and LF02-D), soil pH conditions remained relatively low for the duration of the monitoring period (i.e. February 2013).

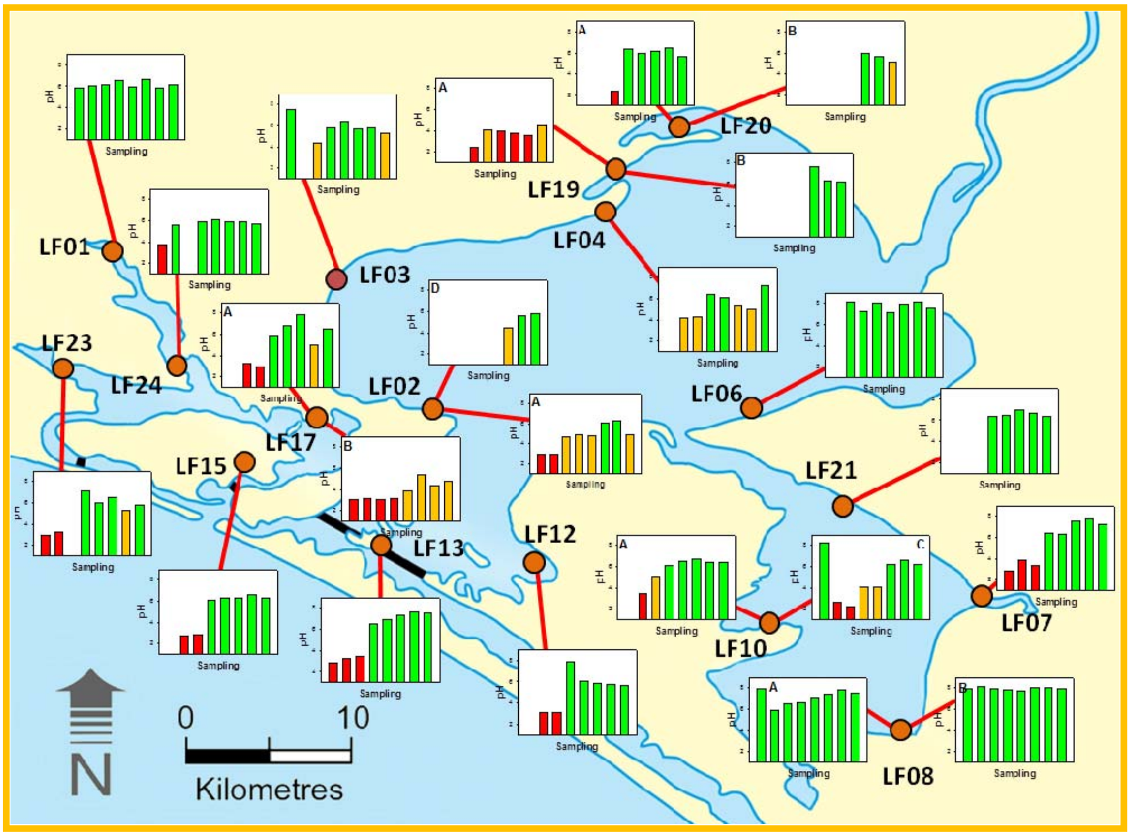


Figure 3-4. **Surface** sediment pH as a function of time/sampling from various study areas around the Lower Lakes. Each plot comprises up to eight vertical bars that represent soil pH conditions (red: pH < 4, orange: pH 4 to 5.5, green: pH > 5.5) for each of the eight sampling occasions between August 2007 and February 2013.

In general, compared to surface sediments, the **middle** of the soil profile (30 to 50 cm) experienced greater acidification and pH conditions remained lower for longer (Figure 3-5). Soil pH conditions were generally lower in Lake Alexandrina and tributaries in comparison to Lake Albert. This may have been related to the construction of a bund at the Narrung Narrows (between Lakes Alexandrina and Albert) in February 2008, which was to artificially maintain water levels in Lake Albert by pumping water from Lake Alexandrina. Hence, water levels were maintained at a higher level for longer (compared to Lake Alexandrina; Figure 1-1) and oxidation and subsequent acidification and low pH conditions did not penetrate as deep in to the profile.

At Point Sturt (sands: Figure 3-3, LF02-D) and Dog Lake (sands over clay, LF19-A), soil pH remained less than pH 4 (sulfuric) for the duration of the monitoring period (i.e. to February 2013). Sediment pH remained above 5.5 in the middle of the profile at Poltalloch Station (sands, LF06) and Meningie (sand over clay, LF08).

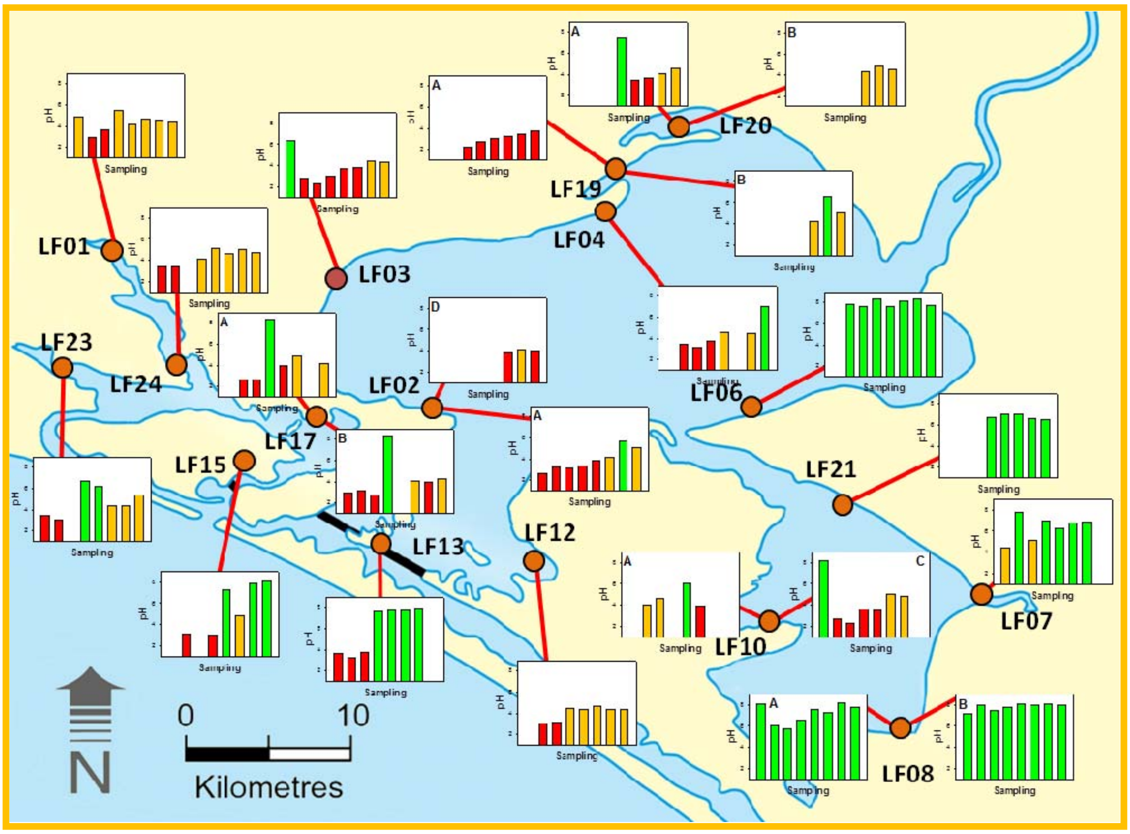


Figure 3-5. pH of sediments from the **middle** of the soil profile (30 to 50 cm) as a function of time/sampling from various study areas around the Lower Lakes. Each plot comprises up to eight vertical bars that represent soil pH conditions (red: pH < 4, orange: pH 4 to 5.5, green: pH > 5.5) for each of the eight sampling occasions between August 2007 and February 2013.

Sediments from the **bottom** (> 60 cm) of the soil profile generally experienced less acidification and higher pH both during and after the drought (Figure 3-6). This was most likely because these sediments were below the maximum depth of oxidation that occurred during the drought. Where pH did drop below 5.5, low pH conditions prevailed for many months after inundation (e.g. LF03, LF10 and LF24).

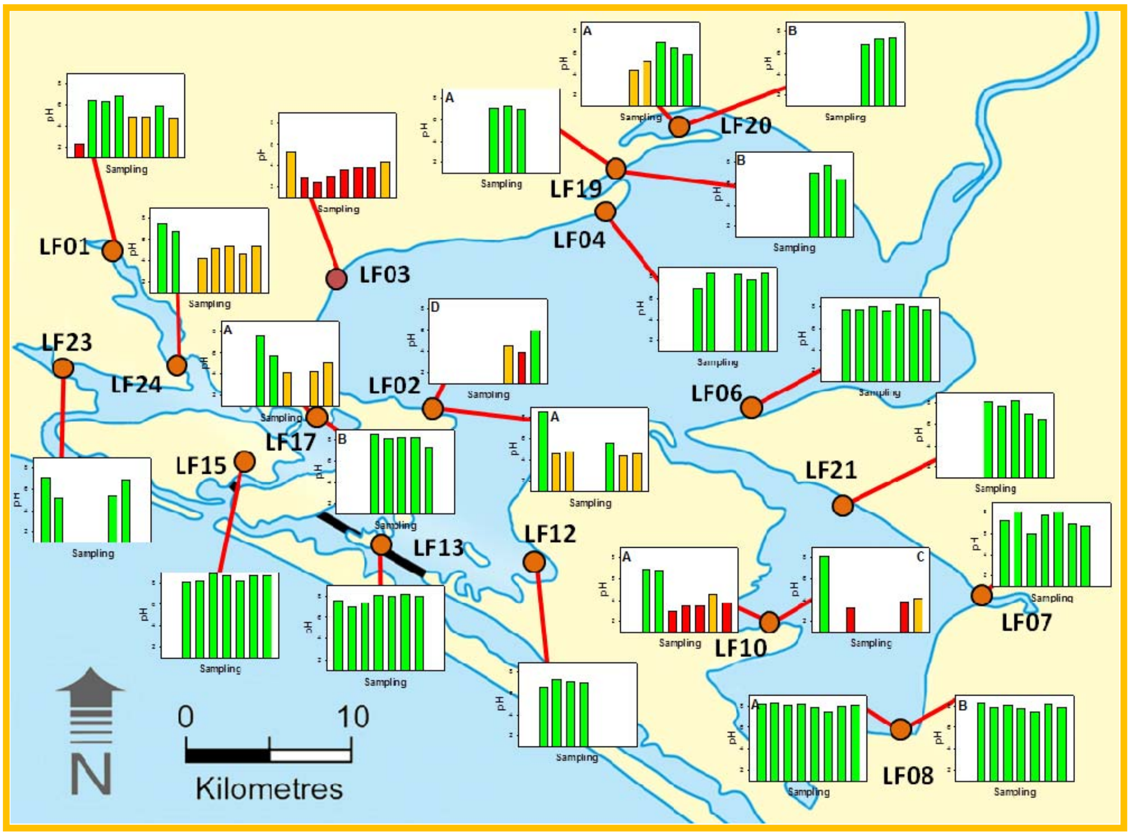


Figure 3-6. pH of sediments from the **bottom** of the soil profile (> 60 cm) as a function of time/sampling from various study areas around the Lower Lakes. Each plot comprises up to eight vertical bars that represent soil pH conditions (red: pH < 4, orange: pH 4 to 5.5, green: pH > 5.5) for each of the eight sampling occasions between August 2007 and February 2013.

Detailed examples

Changes in soil pH varied widely around the Lower Lakes during drought and subsequent recovery. Some specific examples of how soil pH changed through time are shown in Figure 3-7. Additional plots and supporting data are presented in Appendix A.

At Milang (LF03-A), drought caused sediment pH to fall to less than 5.5 at all depths in the soil profile (Figure 3-7: LF03-A). During the drought period (Samplings a and b), soil pH fell below 4 (sulfuric) in all layers except the sandy surface sediments which fell to below pH 5.5. Subsequent inundation caused a relatively rapid neutralisation of the surface sediments and pH increased to more than pH 6. Soil material deeper in the profile took longer to neutralise and inundation caused a slight increase in pH, followed by a steady but slow increase during the subsequent samplings. Soil pH below a depth of about 25 cm remained sulfuric for more than 18 months after inundation and was below 5.5 at the end of the monitoring period in February 2013.

At Waltowa (LF07-A), drought caused soil pH near the top of the profile (< 35 cm) to fall below 4 (Figure 3-7: LF07-A). Subsequent inundation in these sands caused relatively rapid neutralisation of surface sediments and pH rose to greater than 6 within 10 months. Soil materials deeper in the profile were not as severely impacted by drought. For sediments deeper than 35 cm, soil pH generally remained above 5.5 for the duration of the monitoring period.

At Meningie (LF08-A/B), soil pH was not impacted by drought in any way (Figure 3-7: LF08-B). The entire profile remained circumneutral for the duration of the monitoring period.

At Campbell Park (LF10-C), drought caused acidification of all sandy soil layers within the profile (Figure 3-7: LF10-C). Soil pH fell from greater than 8 to less than 4 (sulfuric) from surface to the maximum depth of investigation at 80 cm. Following inundation, there was a steady neutralisation of all soil layers. Recovery occurred most rapidly in the surface sediments with pH increasing from a low of 2.5 during to drought to greater than 4 during Samplings c and d (10 and 16 months after inundation respectively) to greater than 6 by Sampling e (22 months after inundation). Similar neutralisation trends occurred deeper (> 20 cm) in the profile but soil conditions remained acidic for far longer after inundation. Sediment from the bottom of the profile remained sulfuric for more than 2 years after inundation. Additionally, sediment from the middle and bottom of the profile had soil pHs that persisted below 5.5 for the duration of the monitoring period (i.e. February 2013).

At Loveday Bay (LF12-C), drought caused soil pH in the surface and middle (< 50 cm) of the sand profile to fall below 4 (Figure 3-7: LF12-C). Soil material from the bottom of the profile (> 50 cm) did not acidify and pH remained above 6.5 for the duration of the monitoring period. Following inundation, surface sediment were neutralised relatively rapidly (within 10 months) and pH increased from less than 3.5 to greater than 7. Soil material from the middle of the profile (10 to 50 cm) experienced an initial increase in pH from less than pH 3.5 to just over pH 4 within 10 months of inundation. However, there were no subsequent changes during the following 2 years and soil pH remained below 4.5 for the duration of the monitoring period (i.e. February 2013).

At Tauwitcherie (LF13-A), drought caused soil pH in the surface and middle (< 30 cm) of the profile to fall below 4 (Figure 3-7: LF13-A). Soil material from the bottom of the profile (> 30 cm) did not acidify and pH generally remained above 7 for the duration of the monitoring period. Following inundation, acidified sediment above 30 cm were neutralised relatively rapidly and pH increased from less than 4 to greater than 6.5 within 10 months.

At Dog Lake (LF19-A), drought caused soil pH in the surface and middle (< 40 cm) of the sandy profile to fall below 4 (Figure 3-7: LF19-A). Soil material from the bottom (clay) of the profile (> 40 cm) did not acidify and pH remained above 7 for the duration of the monitoring period. Following inundation, soil conditions remained acidic and pH was around 4 within the surface and middle of the profile (> 2 years after inundation). Soil material from the middle of the profile remained sulfuric (pH < 4) for the duration of the monitoring period (i.e. February 2013).

At Boggy Lake (LF20-A), drought caused soil pH throughout the dominantly clay profile to drop to less than 4 (Figure 3-7: LF20-A). Following inundation, pH of soil material above 50 cm rose from less than 3 to greater than 6 within 10 months (Sampling c). Soil material below a depth of 50 cm maintained a pH of approximately 4. The pH of surface sediments remained above 6 for the remainder of the monitoring period (i.e. February 2013). In contrast, following an initial increase in pH to greater than 6 (Sampling c), soil material from layers 2, 3 and 4 exhibited a fall/return in pH to around 4, where it remained for the remainder of the monitoring period (i.e. February 2013; also see Appendix A).

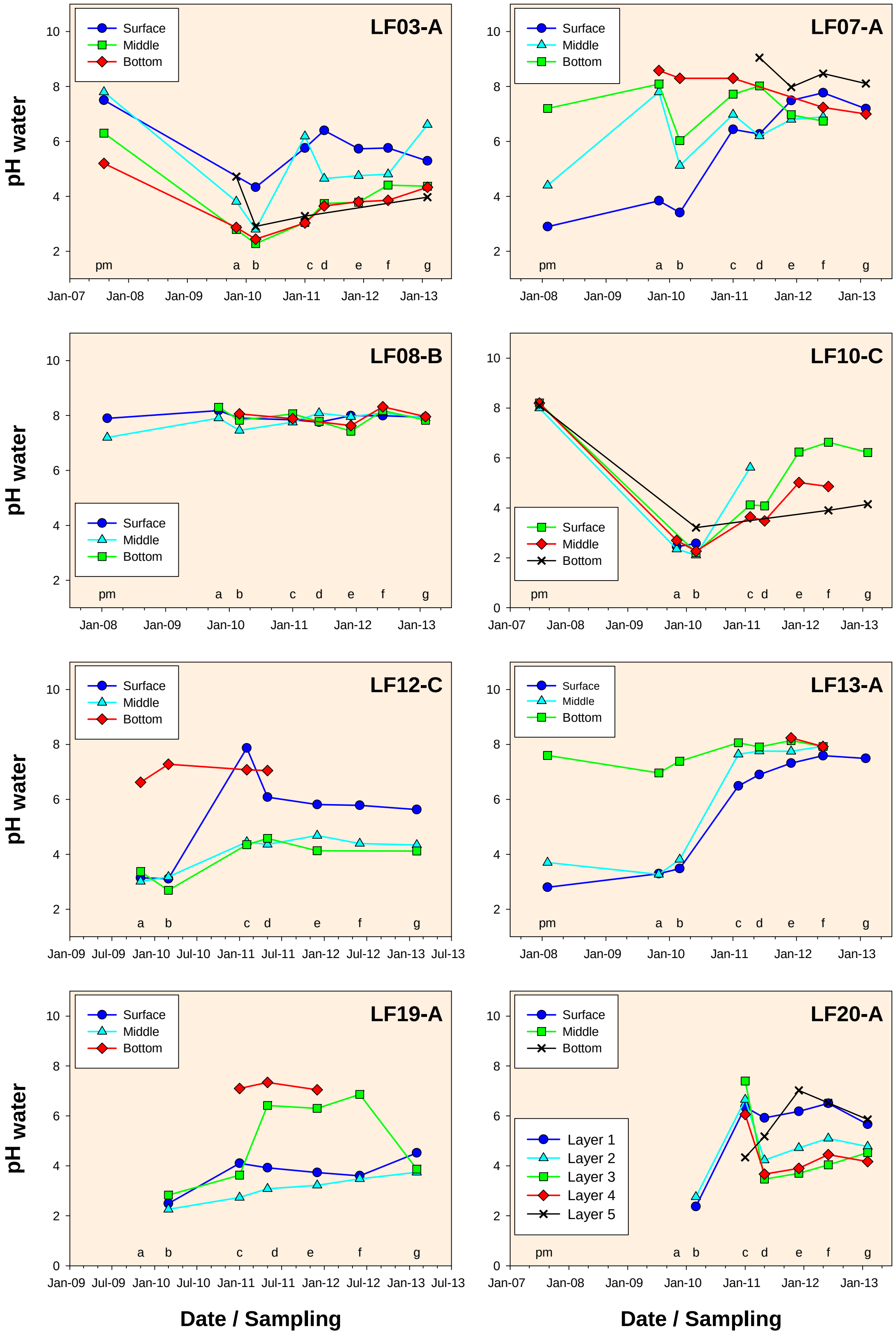


Figure 3-7. pH of sediments from selected profiles around the Lower Lakes. All sampled sediment horizons are represented as layers 1 to a maximum of 5 (increasing with depth). Surface, middle and bottom layers are also highlighted and relate to the data presented in Figure 3-4 to Figure 3-6.

3.4 pH incubation (pH_{inc})

pH incubation (pH_{inc}) experiments were carried out for each of the lake sediment samples collected between August 2007 and February 2013. This involved keeping laboratory samples moist for a specified period (> 10 week), thus allowing a relatively realistic oxidation of sulfide minerals to occur. The resultant drop in pH was measured and used to infer potential impacts of oxidation caused by drought conditions in the Lower Lakes.

Generally, pH_{inc} experiments produced relatively consistent temporal results for a given site or soil horizon (Figure 3-8 to Figure 3-10). However, variations were significant spatially and with depth, as well as with soil texture. In **surface** sediments, soil material from Lake Alexandrina and tributaries were dominantly sulfuric (pH < 4) or hypersulfidic (drop in pH to 4 or less following incubation) (Figure 3-8). Hotspots for potential acidification of surface sediments exist on the northern margins of Lake Alexandrina (LF04, LF19 and LF20), the northern side of Point Sturt (LF02), Loveday Bay (LF12), Currency Creek (LF23) the northern side of Lake Albert (LF07 and LF21) and at Campbell Park (LF10). Slightly less significant pH falls occurred in surface sediments in the Finniss River (LF01 and LF24). Only two sites investigated showed no or little prospect of drought induced, surface soil acidification (LF06 and LF08-B). These were associated with relatively high concentrations of ANC and low or negative NA (See sections 3.8 and 3.9 respectively). The remainder of the sites around Lakes Alexandrina and Albert showed some variation in pH_{inc} through time (i.e. green, orange and red bars: Figure 3-8). These fluctuations were generally associated with sandy soil material (Section 3.2) and were most likely related to spatial heterogeneity of both acidity and ANC. In these surficial sands, it is not uncommon to have small pockets of reduction (CRS formation) that are capable of causing rapid and significant drops in pH.

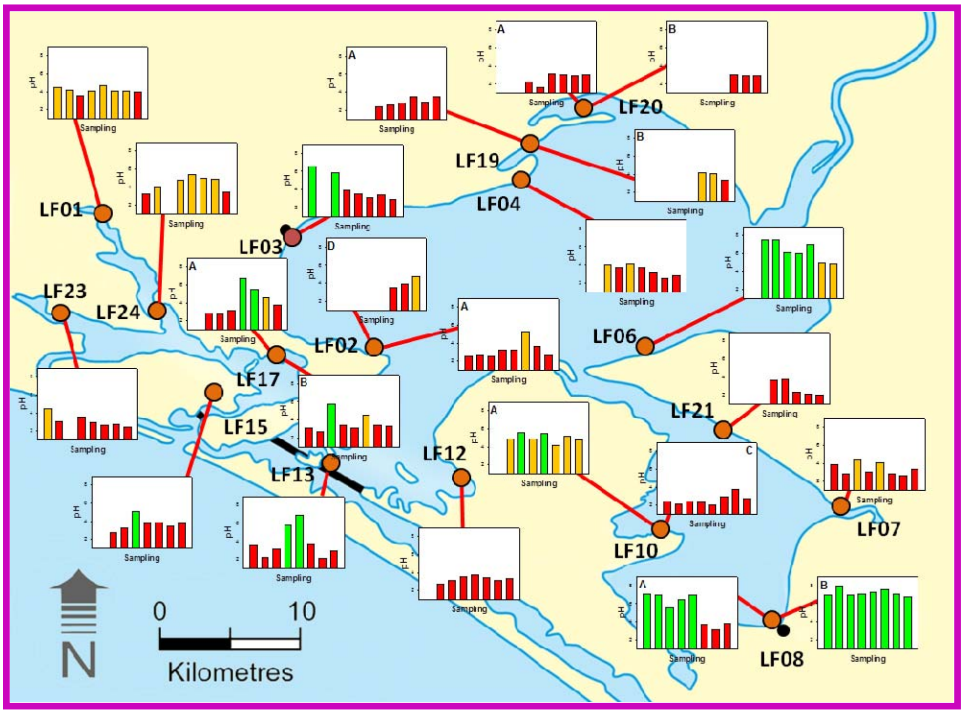


Figure 3-8. **Surface** sediment pH_{inc} (> 10 weeks incubation) as a function of time/sampling from various study areas around the Lower Lakes. Each plot comprises up to eight vertical bars that represent soil pH_{inc} conditions (red: pH < 4, orange: pH 4 to 5.5, green: pH > 5.5) for each of the eight sampling occasions between August 2007 and February 2013.

In sediments from the **middle** of the profile (30 to 50 cm), soil material from the Lower Lakes and tributaries were dominantly sulfuric (pH < 4) or hypersulfidic (drop in pH to 4 or less following incubation) (Figure 3-9). Only two sites investigated showed no or little prospect of potential drought induced, surface soil acidification (LF06 and LF08-B). These were associated with relatively high concentrations of ANC and low or negative NA (See sections 3.8 and 3.9 respectively). Three sites showed some variation in pH_{inc} through time (i.e. green, orange and red bars) and included Boggy Creek (LF15), Tauwitcherie (LF13) and Meningie (LF08-A). In each of these cases, these differences in pH_{inc} can be attributed to localised variability in ANC associated with discontinuous shelly layers (detailed comparison provided in Appendix A).

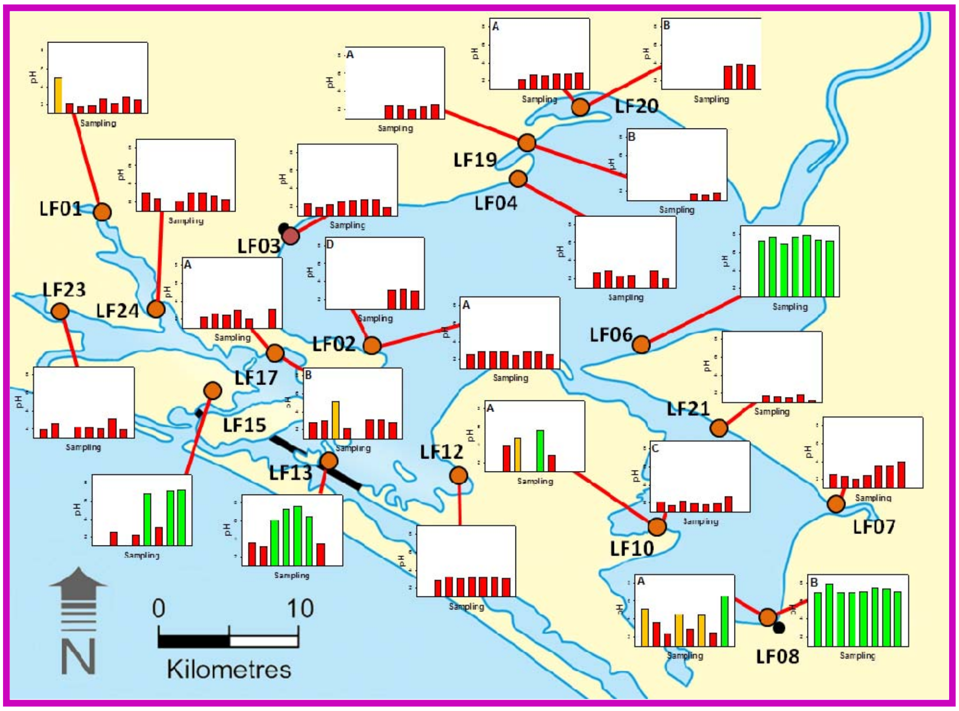


Figure 3-9. pH_{inc} (> 10 weeks incubation) of sediments from the **middle** of the soil profile (30 to 50 cm) as a function of time/sampling from various study areas around the Lower Lakes. Each plot comprises up to eight vertical bars that represent soil pH_{inc} conditions (red: pH < 4, orange: pH 4 to 5.5, green: pH > 5.5) for each of the eight sampling occasions between August 2007 and February 2013.

Generally, sediments from the **bottom** of the soil profile demonstrated less potential to acidify than those from surface and middle layers (Figure 3-10). At many sites, elevated CRS (Figure 3-13) was accompanied by relatively high concentrations of ANC (Section 3.8; e.g. sites LF12, LF07, LF21 and LF20-A). This meant that the NA of these samples was generally low or negative (Section 3.9) and acidification is unlikely during future drought.

Those that did show potential to acidify contained significant quantities of CRS (Figure 3-13) and no or limited ANC (Figure 3-22; e.g. sites LF12, LF07, LF21 LF20-A). This meant that basal sediments from these sites had high positive NA (Figure 3-25). These sediments have the potential to acidify during future, more extreme droughts that may cause water levels to fall below those recorded during the Millennium Drought.

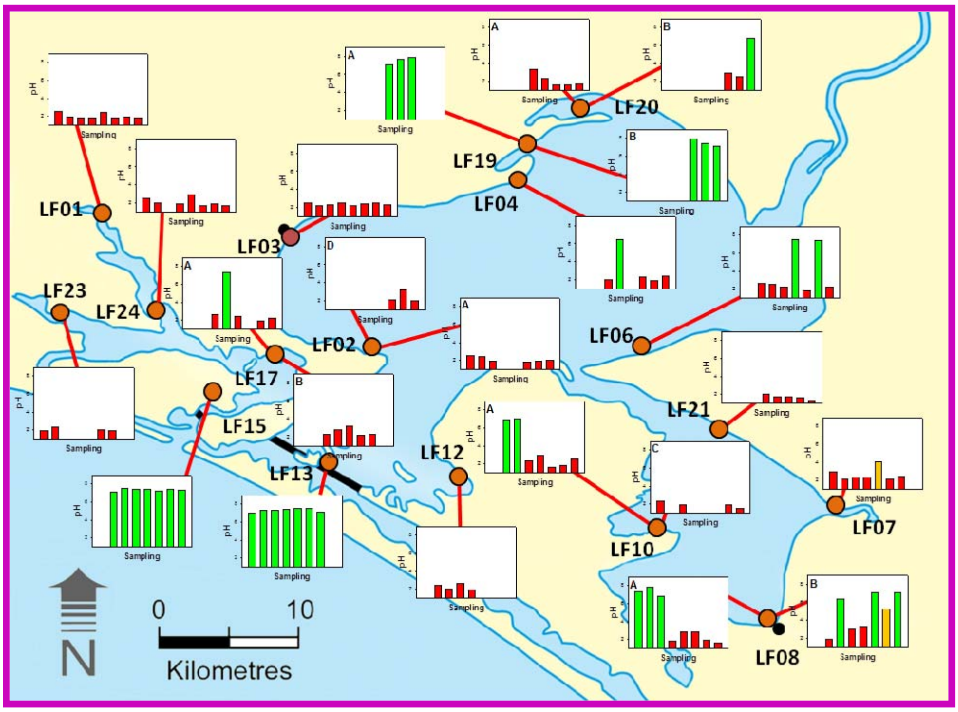


Figure 3-10. pH_{inc} (> 10 weeks incubation) of sediments from the **bottom** of the soil profile (> 60 cm) as a function of time/sampling from various study areas around the Lower Lakes. Each plot comprises up to eight vertical bars that represent soil pH_{inc} conditions (red: pH_{inc} < 4, orange: pH_{inc} 4 to 5.5, green: pH_{inc} > 5.5) for each of the eight sampling occasions between August 2007 and February 2013.

3.5 Chromium-Reducible Sulfur (CRS)

Chromium-Reducible Sulfur (CRS) is reduced sulfur measured by iodometric titration after acidic chromous chloride reduction and comprises the potential sulfidic acidity store in ASS. Changes in CRS concentration are a good indicator of the redoximorphic conditions dominating the soil profile. In a sulfate rich environment, CRS is likely to be relatively high if labile organic matter is not limiting and concentrations could potentially increase under prolonged, reducing, subaqueous conditions.

CRS was measured in each of the lake sediment samples collected between August 2007 and February 2013. In **surface** sediments, consistently significant concentrations of CRS were only measured in Lower Finniss River (LF24; Figure 3-11). All the other sites showed either variable or relatively low concentrations of CRS in surface sediments. This was most likely related to drought induced oxidation of original CRS, particularly with sandy soil textures that facilitated rapid drying. Data from limited pre-monitoring sampling (pm), that was carried out before water levels dropped below 0 m AHD (August 2007 - Figure 1-1), illustrates how drought induced oxidation caused depletion in CRS concentrations (LF03 and LF10-C: Figure 3-11). At Campbell Park (LF10-C), CRS fell from pre-drought levels of more than 650 mol H^+/t to less than 10 mol H^+/t during the drought (Sampling a; Figure 3-11). At Milang (LF03), CRS concentrations fell from pre-drought levels of 34 mol H^+/t to below detection limit during the drought (Sampling b). Following inundation (between samplings b and c), CRS at Milang increased steadily until it returned to pre-drought concentrations of 31 mol H^+/t in February 2013 (Sampling g). At Campbell Park, inundation facilitated the formation of a similar quantity of CRS (30 mol H^+/t) but this was well below the levels measured before the drought (> 650 mol H^+/t).

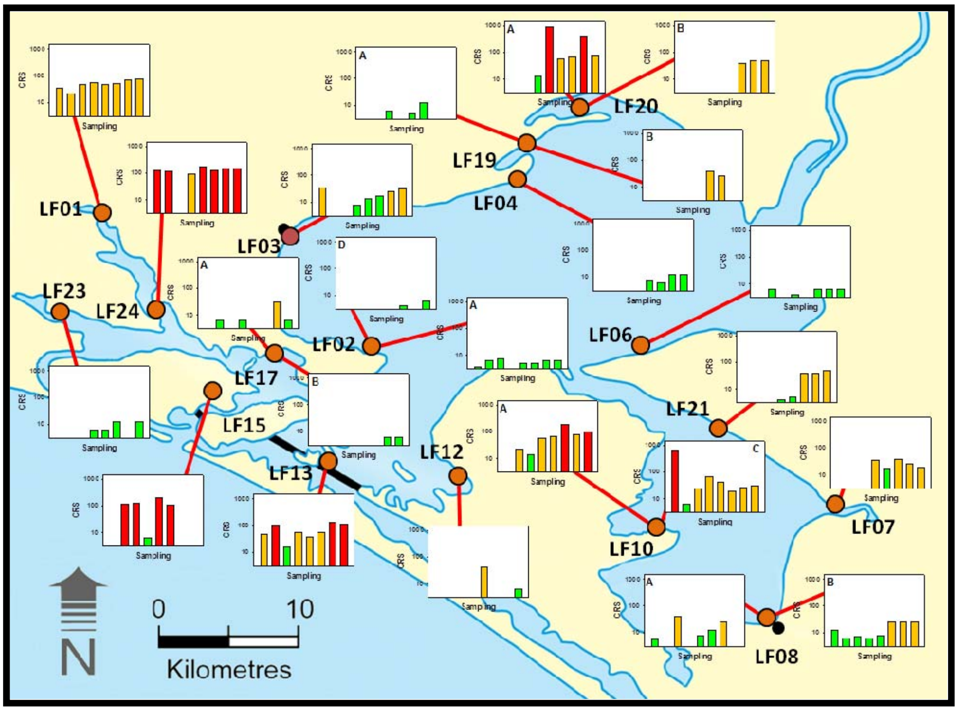


Figure 3-11. CRS in **surface** sediment as a function of time/sampling from various study areas around the Lower Lakes. Each plot comprises up to eight vertical bars that represent soil CRS (Green: < 19 mol H^+/t, orange: 19 to 100 mol H^+/t, red: > 100 mol H^+/t) for each of the eight sampling occasions between August 2007 and February 2013. **Note:** Y-axis: log scale from 3 to 1500 mol H^+/t.

In contrast to surface sediments, soil material from the **middle** of the profile often contained elevated concentrations of CRS (Figure 3-12). This was most likely related to high pre-drought CRS concentrations and incomplete oxidation of sulfides. Inhibition of sulfide oxidation may been related to armouring and in some cases insufficient water caused by rapid drying of sediments during low inflows.

A significant store of acidity, in the form of CRS, is present within soil material from the middle of the profile (Figure 3-12). This means that at many sites, drought induced oxidation has the potential to cause significant drops in pH (Section 3.4). In some instances (LF08-B and some samples from LF13 and LF15), relatively high concentrations of CRS were accompanied by significant quantities of ANC (Section 3.8), thus resulting in low or negative NA (Section 3.9). This meant that although soil material from these sites contained significant CRS, they did not have the potential to acidify as discussed in Section 3.4.

Once again, at Campbell Park (LF10-C), CRS fell from high pre-drought concentrations with the equivalent of more than 1400 mol H^+/t to less than 100 mol H^+/t during the drought (Sampling a; Figure 3-12). There was no steady increase in CRS at Campbell park following inundation, with levels staying relatively constant at between 40 and 100 mol H^+/t.

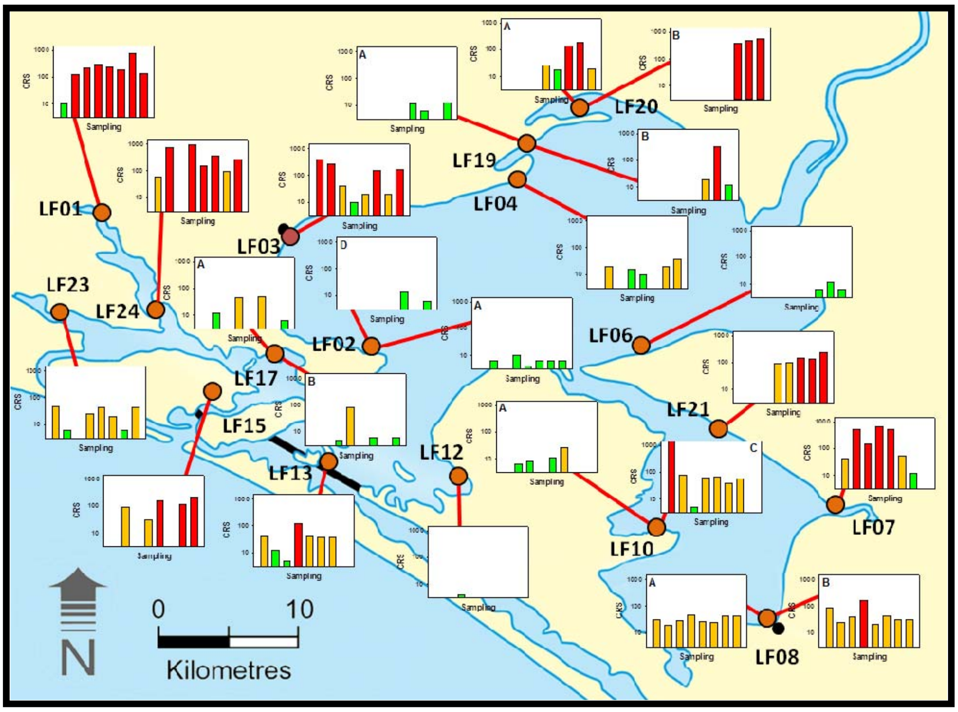


Figure 3-12. CRS in sediments from the **middle** of the soil profile (30 to 50 cm) as a function of time/sampling from various study areas around the Lower Lakes. Each plot comprises up to eight vertical bars that represent soil CRS (Green: 0 to 19 mol H^+/t, orange: 19 to 100 mol H^+/t, red: > 100 mol H^+/t) for each of the eight sampling occasions between August 2007 and February 2013. **Note:** Y-axis: log scale from 3 to 1500 mol H^+/t.

The highest CRS concentrations were measured in soil material from the **bottom** of the profile (Figure 3-13). This was most likely related to both soil texture and the maximum depth of oxidation that occurred during the Millennium Drought. Many of the study sites that were investigated around the Lower Lakes comprised sand overlying medium to heavy clay at the base of the profile (Section 3.2). These clays often contained CRS concentrations with an equivalent of more than 500 mol H^+/t (e.g. LF01, LF04, LF07, LF08, LF19, LF20 and LF24). In addition, at many of these sites, water levels did not fall low enough to promote oxidation of sulfides within these bottom layers. At the bottom of the profile, many sites showed little or no signs of oxidation and soil pH remained circumneutral during and after the drought period (Figure 3-6).

These elevated concentrations of CRS contributed to high NA (Figure 3-25) and a significant risk of acidification during more extreme drought scenarios (more severe than the Millennium Drought). Although many of these sediments also contained significant quantities of ANC, there was often insufficient to neutralise the potential acidity store (Section 2.8). This was demonstrated by pH incubation experiments that indicated that many of these bottom sediments have the potential to become sulfuric (pH < 4) when dried (Section 3.4).

A few sites did contain very high levels of CRS accompanied by sufficient concentrations of ANC to neutralise the potential acidification hazard (e.g. LF19-A and LF19-B). Bottom sediments from these sites had negative NA (Figure 3-25) and incubation experiments indicated that they were unlikely to acidify during future drought scenarios (Figure 3-10). Nevertheless, they may pose a significant source of potential contaminants.

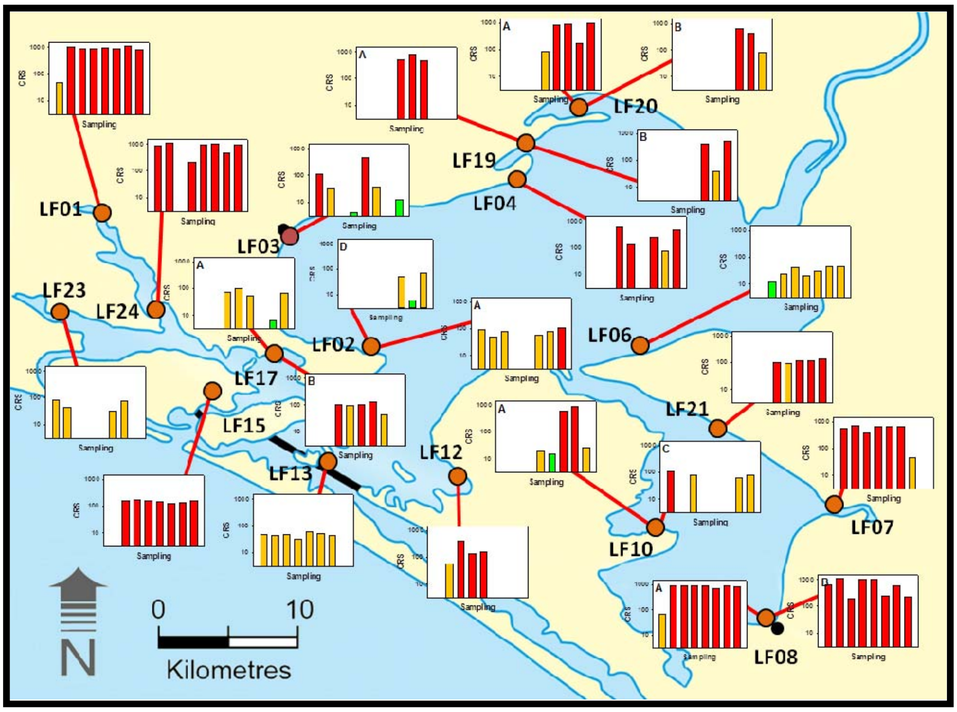


Figure 3-13. CRS in sediments from the **bottom** of the soil profile (> 60 cm) as a function of time/sampling from various study areas around the Lower Lakes. Each plot comprises up to eight vertical bars that represent soil CRS (Green: 0 to 19 mol H^+/t, orange: 19 to 100 mol H^+/t, red: > 100 mol H^+/t) for each of the eight sampling occasions between August 2007 and February 2013. **Note:** Y-axis: log scale from 3 to 1500 mol H^+/t.

3.6 Titratable Actual Acidity (TAA)

Titratable Actual Acidity (TAA) is a measure of the weakly sorbed existing acidity (and metal ions in solution) in ASS materials that have oxidised. It is measured via acidity titration to pH 6.5 with standardised NaOH in a 1:40 suspension in 1 M potassium chloride.

TAA was measured in each of the lake sediment samples collected between August 2007 and February 2013. In **surface** sediments, the highest concentrations of TAA were measured at Campbell Park (LF10), the northern margins of Lake Alexandrina (LF19 and LF20), in Finniss River (LF01 and LF24), at Boggy Creek (LF15) and Tauwitcherie (LF13; Figure 3-14). As might be expected, the highest concentrations of TAA measured at each site were recorded during the drought period (Samplings a and b) and were associated with sites that had become sulfuric (e.g. LF10, LF13, LF15, LF19-A, LF20-A and LF24). Data from limited pre-monitoring sampling (pm) that was carried out before water levels dropped below 0 m AHD (August 2007 - Figure 1-1) illustrates how the drought induced oxidation caused a dramatic increase in TAA concentrations (LF10-A and LF10-C: Figure 3-14). TAA was not present at either site prior to the drought and rose to above 150 mol H^+/t during Samplings a and b.

The persistence of TAA in surface sediments was in many cases related to soil texture (Section 3.2). Where surface soils comprised clay rich material, TAA concentrations remained higher for longer after inundation (e.g. LF 01, LF19-A, LF20-A, LF20-B and LF24). Where sand dominated surface soils, TAA was rapidly flushed out of the sediment following inundation (e.g. LF02-A, LF10-A, LF10-C, LF13, LF15 and LF17).

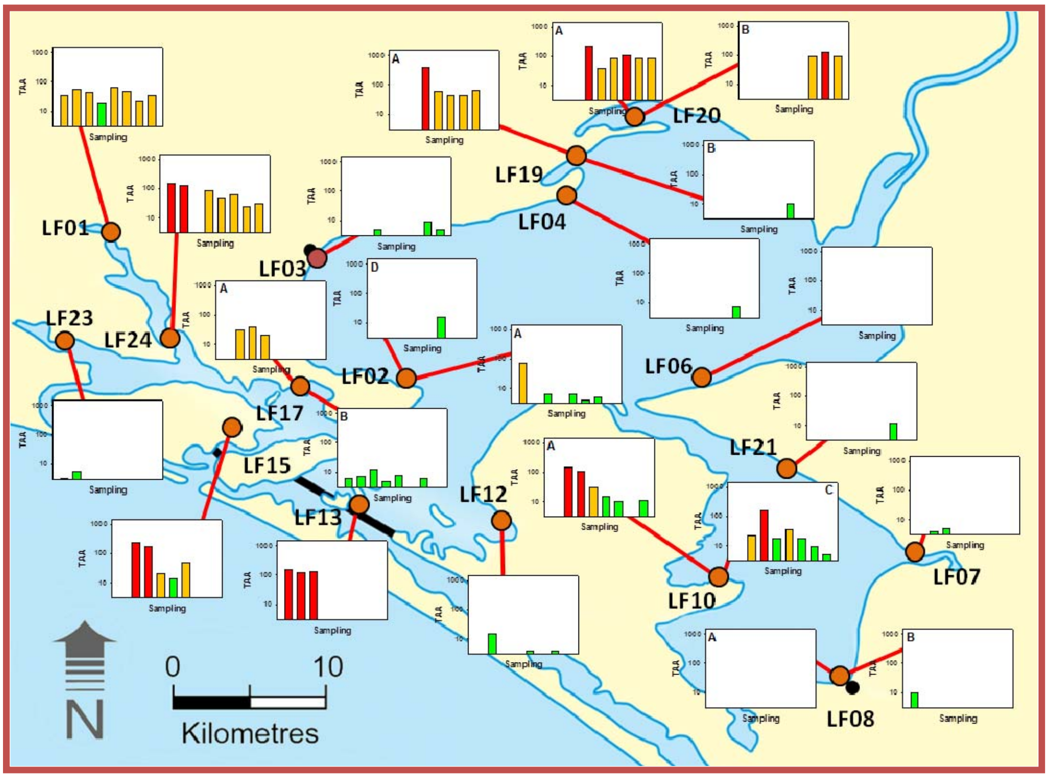


Figure 3-14. TAA in **surface** sediment as a function of time/sampling from various study areas around the Lower Lakes. Each plot comprises up to eight vertical bars that represent soil TAA (Green: < 19 mol H^+/t, orange: 19 to 100 mol H^+/t, red: > 100 mol H^+/t) for each of the eight sampling occasions between August 2007 and February 2013. **Note:** Y-axis: log scale from 3 to 1500 mol H^+/t.

In the **middle** of the soil profile, the highest TAA concentrations were measured on the northern margin of Lake Alexandrina (LF03, LF19-A, LF20-A and LF20-B) and in the Finniss River (LF01 and LF24; Figure 3-15). These sites acidified during the drought, and low pH conditions (Figure 3-5) and elevated TAA persisted for a more than two years after inundation. These soil layers comprised clay rich material that contained large stores of acidity and were less likely than the sand to be flushed during reflooding.

Elsewhere in the Lakes, much lower concentrations of TAA (and NA: Section 3.9) were associated with soil material from the middle of the profile. Generally, these soil layers were dominated by sand (Section 3.2) with lower overall acid generating potential (i.e. NA: Section 3.9). However, it should be noted that even though these layers had comparatively low concentrations of TAA, they were still subject to acidification during drought, probably because of the poor buffering capacity of sand, and in some instances these took a long time to neutralise (Section 3.3).

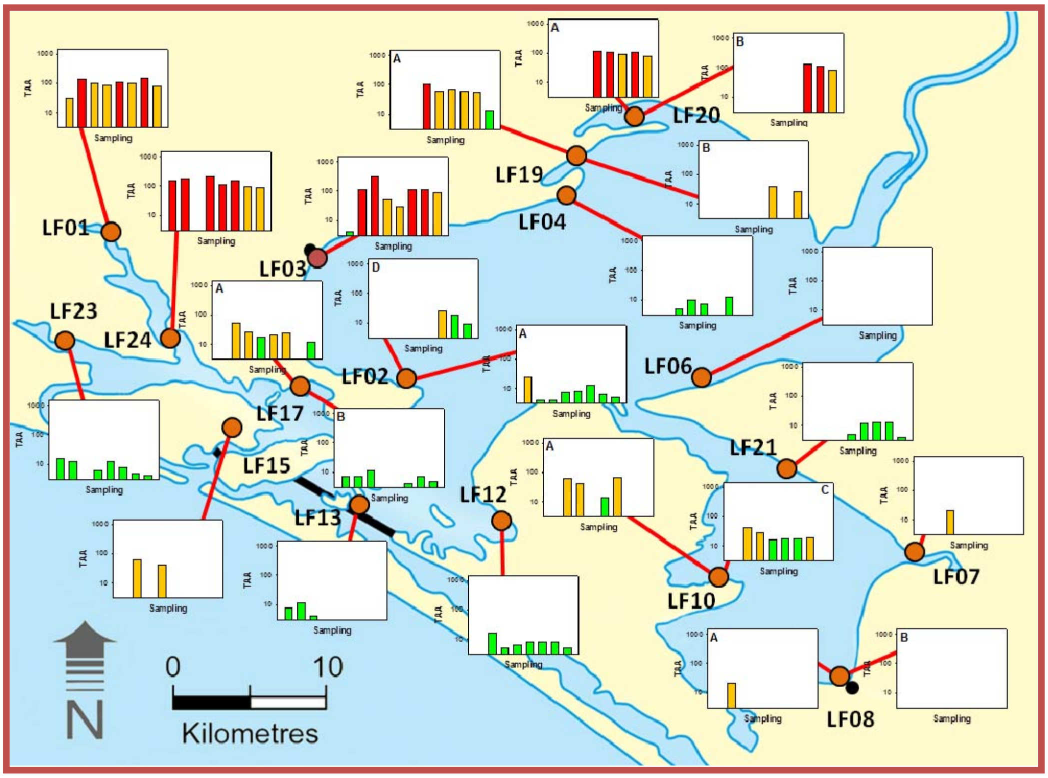


Figure 3-15. TAA in sediments from the **middle** of the soil profile (30 to 50 cm) as a function of time/sampling from various study areas around the Lower Lakes. Each plot comprises up to eight vertical bars that represent soil TAA (Green: 0 to 19 mol H^+/t, orange: 19 to 100 mol H^+/t, red: > 100 mol H^+/t) for each of the eight sampling occasions between August 2007 and February 2013. **Note:** Y-axis: log scale from 3 to 1500 mol H^+/t.

Soil material from the **bottom** of the profile generally had lower concentrations of TAA than the overlying layers (Figure 3-16). In many instances, this was most likely because the maximum depth of drought induced oxidation did not reach these deeper sediments. This is supported by the observation that most of these soil layers never acidified during the drought, even though they had positive NA (Figure 3-25) and pH incubation experiments indicated that they would acidify if dried (Figure 3-10).

A slightly unusual situation was noted at site LF01, where high TAA concentrations and NA (> 100 mol H^+/t) were associated with only slightly acidic soil pH conditions (ranging from 5 to 7; Figure 3-6). This is most likely because the TAA was associated with metal ions (e.g. Fe^{2+} and Al^{3+}) weakly sorbed or in solution rather than H^+ ions.

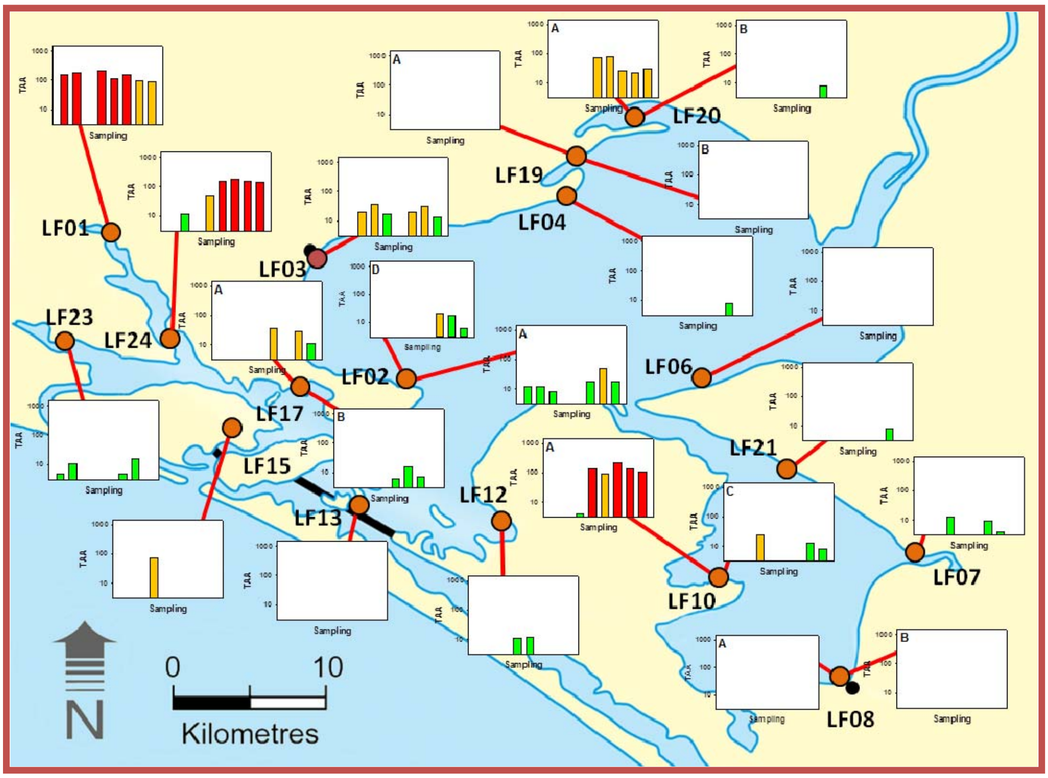


Figure 3-16. TAA in sediments from the **bottom** of the soil profile (> 60 cm) as a function of time/sampling from various study areas around the Lower Lakes. Each plot comprises up to eight vertical bars that represent soil TAA (Green: 0 to 19 mol H^+/t, orange: 19 to 100 mol H^+/t, red: > 100 mol H^+/t) for each of the eight sampling occasions between August 2007 and February 2013. **Note:** Y-axis: log scale from 3 to 1500 mol H^+/t.

3.7 Retained Acidity (RA)

Retained Acidity (RA) is the less available fraction of the existing acidity (not measured by TAA) that may be released slowly into the environment by dissolution of relatively insoluble salts (e.g. jarosite, natrojarosite).

In **surface** sediments, RA is most often associated with the drought period during Samplings a and b (e.g. LF10-A, LF13, LF15, LF17-A and LF24; Figure 3-17). At these sites, RA was lost from the system soon after inundation occurred (< 10 months). Surface sediments at these sites were generally sandy (Section 3.2) and the loss of RA was most likely associated with flushing of acidity during reflooding. In contrast, RA persisted in the clay rich surface sediments in Boggy Lake (LF20) until February 2013, more than 2 ½ years after inundation.

In the **middle** of the soil profile, RA generally persisted post-drought for longer than in surface sediments (e.g. LF01, LF03, LF19 and LF20; Figure 3-18). Soil material from the middle of the profile at these sites was dominantly clay (Section 3.2) and associated with high NA (Figure 3-24) and TAA (Figure 3-15). Low soil pH conditions persisted at these sites for up to 2 ½ years after inundation. This suggests that, at these sites, the slow release of acidity from minerals such as natrojarosite plays a significant role in maintaining low pH conditions even after prolonged inundation.

Soil material from the **bottom** of the profile generally contained little or no RA (Figure 3-19). This was because these layers were below the maximum depth of oxidation and did not acidify during the drought (Figure 3-6). The few sites that did contain RA at the bottom of the profile (e.g. LF01, LF03, LF10-A, LF17-A and LF24) were relatively close to the shoreline (i.e. oxidised to greater depths in the profile) and had acidified during the drought (Figure 3-6).

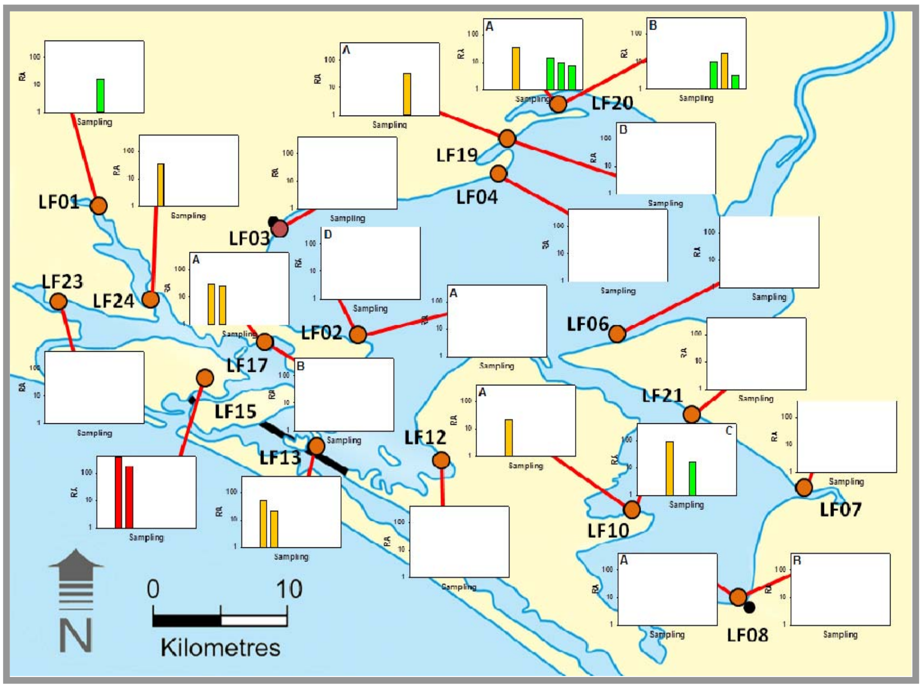


Figure 3-17. RA in **surface** sediment as a function of time/sampling from various study areas around the Lower Lakes. Each plot comprises up to eight vertical bars that represent soil RA (Green: < 19 mol H^+/t, orange: 19 to 100 mol H^+/t, red: > 100 mol H^+/t) for each of the eight sampling occasions between August 2007 and February 2013. **Note:** Y-axis: log scale from 1 to 400 mol H^+/t.

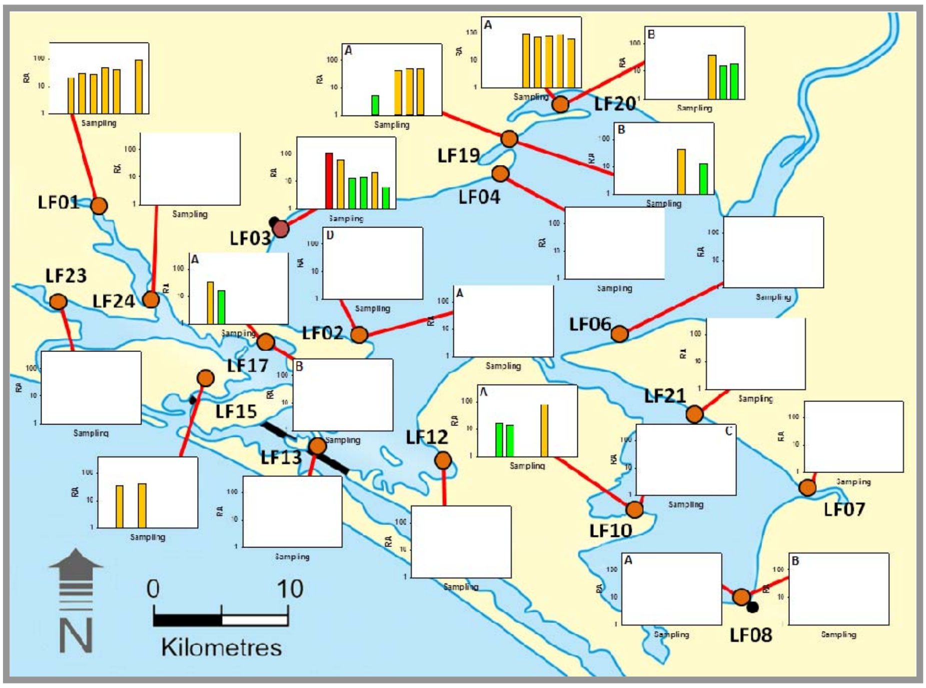


Figure 3-18. RA in sediments from the **middle** of the soil profile (30 to 50 cm) as a function of time/sampling from various study areas around the Lower Lakes. Each plot comprises up to eight vertical bars that represent soil RA (Green: 0 to 19 mol H^+/t, orange: 19 to 100 mol H^+/t, red: > 100 mol H^+/t) for each of the eight sampling occasions between August 2007 and February 2013. **Note:** Y-axis: log scale from 1 to 400 mol H^+/t.

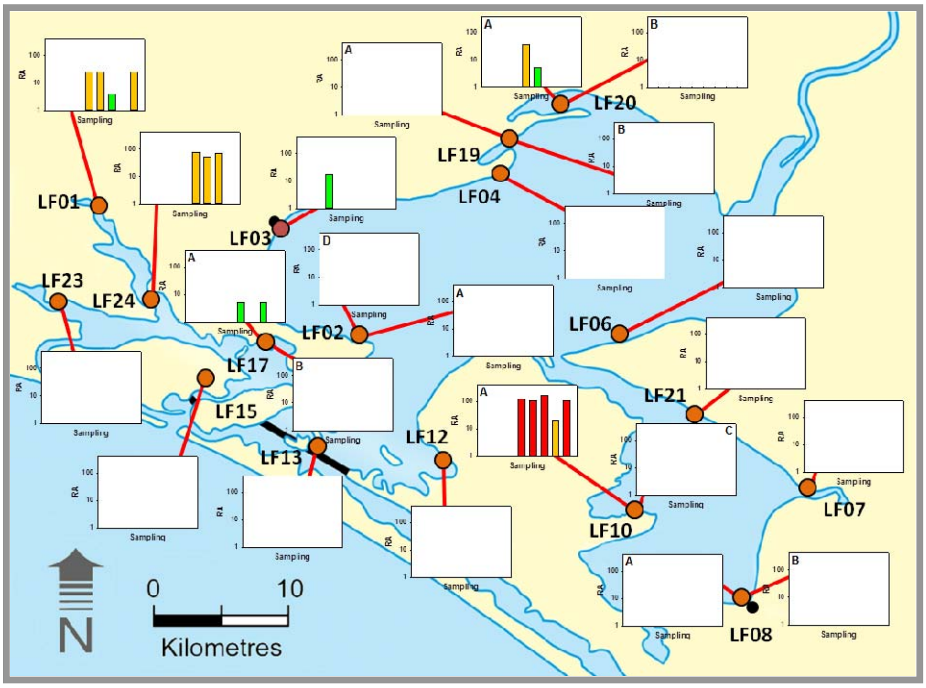


Figure 3-19. RA in sediments from the **bottom** of the soil profile (> 60 cm) as a function of time/sampling from various study areas around the Lower Lakes. Each plot comprises up to eight vertical bars that represent soil RA (Green: 0 to 19 mol H^+/t, orange: 19 to 100 mol H^+/t, red: > 100 mol H^+/t) for each of the eight sampling occasions between August 2007 and February 2013. **Note:** Y-axis: log scale from 1 to 400 mol H^+/t.

3.8 Acid Neutralising Capacity (ANC)

Acid Neutralisation Capacity (ANC) is the soil's ability to neutralise or buffer acidity. ANC was highly variable around the Lower Lakes and it was difficult to identify any clear patterns associated with drought and acidification because of the heterogeneity of the calcium carbonate content (particularly shelly material) in lake sediments. At many sites, soil layers that had no ANC at a given location might contain numerous shells and/or shell fragments, equating to hundreds of mol H^+/tonne acid neutralising capacity, within a couple of square metres.

No clear temporal trends in ANC were exhibited in the surface (Figure 3-20), middle (Figure 3-21) or bottom (Figure 3-22) layers of the soil profiles collected during the monitoring period. Limited pre-monitoring (pm) sampling suggest that some ANC had been diminished by drought induced acidification, as median concentrations were lower than in the pre-monitoring period (Figure 2-9). Some general spatial trends, relating to site location and depth, were identified.

Generally, there was more ANC present at the bottom of profiles compared to the middle and surface layers (Figure 3-20 to Figure 3-22). This was most likely because many of these layers were beyond the maximum depth of drought induced oxidation and because they comprised medium to heavy clays (Section 3.2) that contained higher initial (pre-drought) amounts of ANC. In addition, in surface and middle soil layers, less ANC was present in sediments from Lake Alexandrina and tributaries in comparison to those collected from Lake Albert (Figure 3-20 and Figure 3-21). This may have been related to the construction of a bund at the Narrung Narrows (between Lakes Alexandrina and Albert) in February 2008: water levels were maintained at a higher level for longer (compared to Lake Alexandrina; Figure 1-1), which meant that oxidation and subsequent acidification may not have depleted ANC to as great a depth in the soil profile.

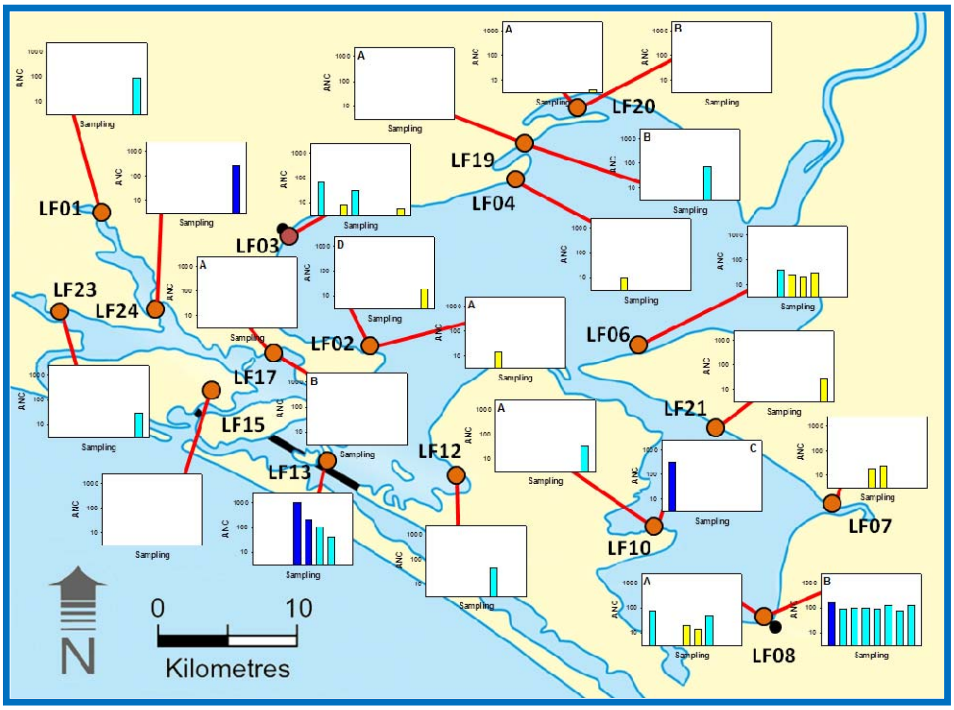


Figure 3-20. ANC of **surface** sediment as a function of time/sampling from various study areas around the Lower Lakes. Each plot comprises up to eight vertical bars that represent soil ANC (Yellow: ANC < 28.5 mol H^+/t, cyan: ANC 28.5 to 150 mol H^+/t, blue: > 150 mol H^+/t) for each of the eight sampling occasions between August 2007 and February 2013. **Note:** Y-axis: log scale from 3 to 1200 mol H^+/t.

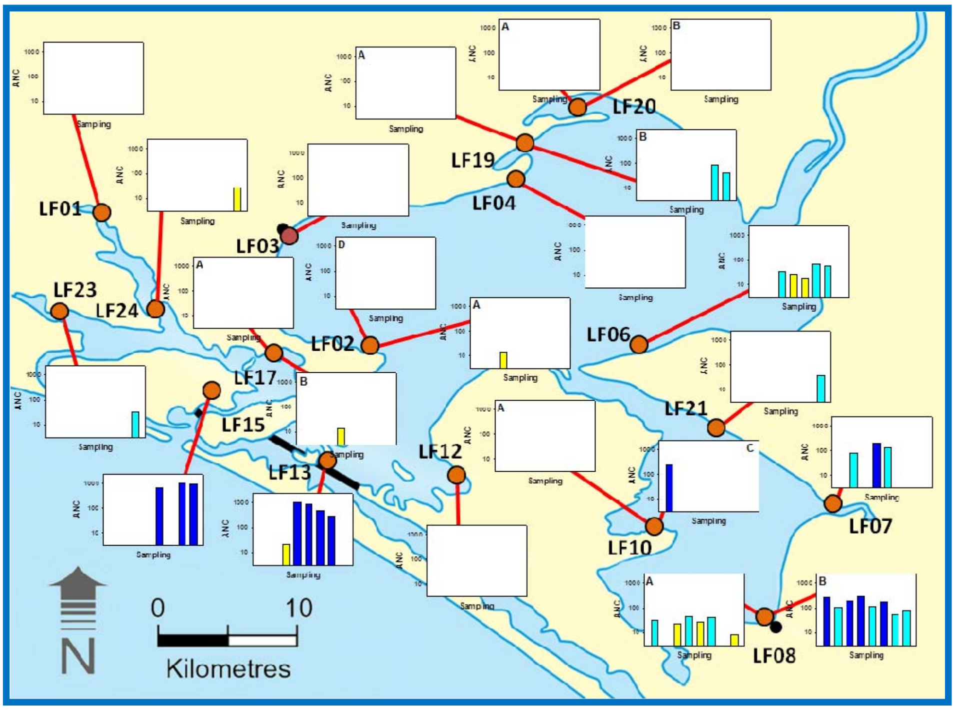


Figure 3-21. ANC of sediments from the **middle** of the soil profile (30 to 50 cm) as a function of time/sampling from various study areas around the Lower Lakes. Each plot comprises up to eight vertical bars that represent soil ANC (Yellow: < 28.5 mol H^+/t, cyan: 28.5 to 150 mol H^+/t, blue: > 150 mol H^+/t) for each of the eight sampling occasions between August 2007 and February 2013. **Note:** Y-axis: log scale from 3 to 1200 mol H^+/t.

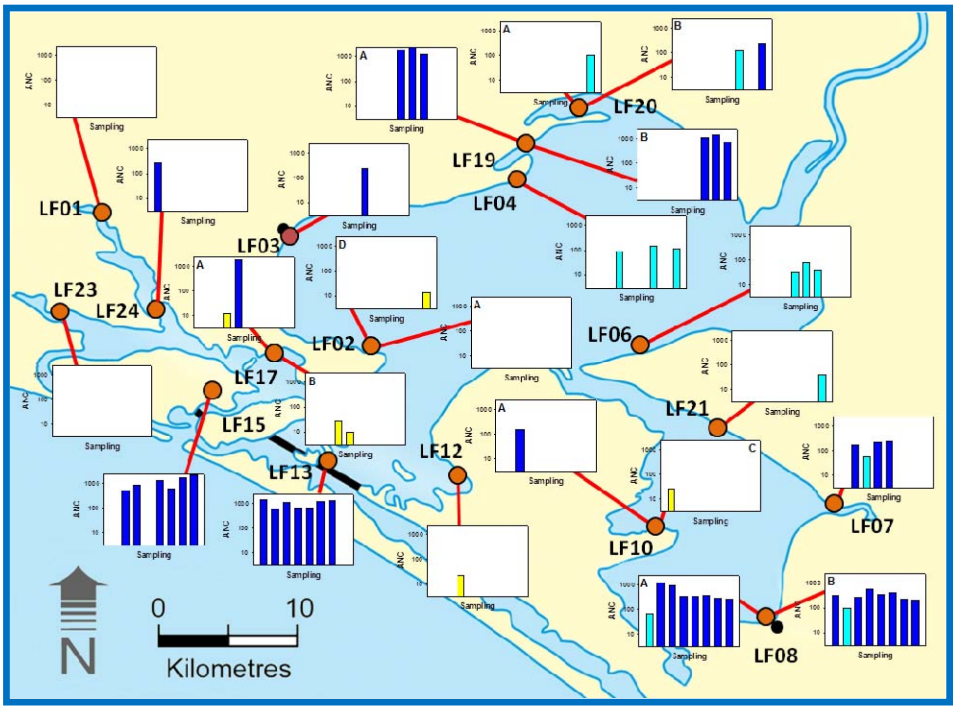


Figure 3-22. ANC of sediments from the **bottom** of the soil profile (> 60 cm) as a function of time/sampling from various study areas around the Lower Lakes. Each plot comprises up to eight vertical bars that represent soil ANC (Yellow: < 28.5 mol H^+/t, cyan: 28.5 to 150 mol H^+/t, blue: > 150 mol H^+/t) for each of the eight sampling occasions between August 2007 and February 2013. **Note:** Y-axis: log scale from 3 to 2500 mol H^+/t.

3.9 Net Acidity (NA)

Net Acidity (NA) is equal to the potential sulfidic acidity (chromium-reducible S - CRS) plus the existing acidity (Titratable Actual Acidity - TAA) plus Retained Acidity (RA - e.g. jarosite) minus the Acid Neutralisation Capacity (ANC) divided a fineness factor of 1.5. Details of the chemical methods used are given in Ahern *et al*. (2004).

Net Acidity was calculated for each lake sediment sample collected during the monitoring period between August 2007 and February 2013. In **surface** sediments, the highest NA's were found at Dog Lake (LF20), Campbell Park (LF10-A), Tauwitcherie (LF13), Boggy Creek (LF15) and Lower Finniss River (LF24; Figure 3-23). Surface soil material at these sites generally comprised clay or peat (Section 3.2) with little or no ANC (Figure 3-20). At Tauwitcherie (LF13), there was a dramatic fall in NA between Sampling b (> 100 mol H^+/t) and Sampling c (< 0 mol H^+/t) that was associated with variations in ANC associated with near surface shelly layers (Section 3.8).

Although surface soil from many sites had NA of less than 19 mol H^+/t (Figure 3-23: green bars), they still had the potential to acidify under drought conditions (Figure 3-9). These sediments were dominantly sands and probably acidified because of their poor buffering capacity (Section 3.3).

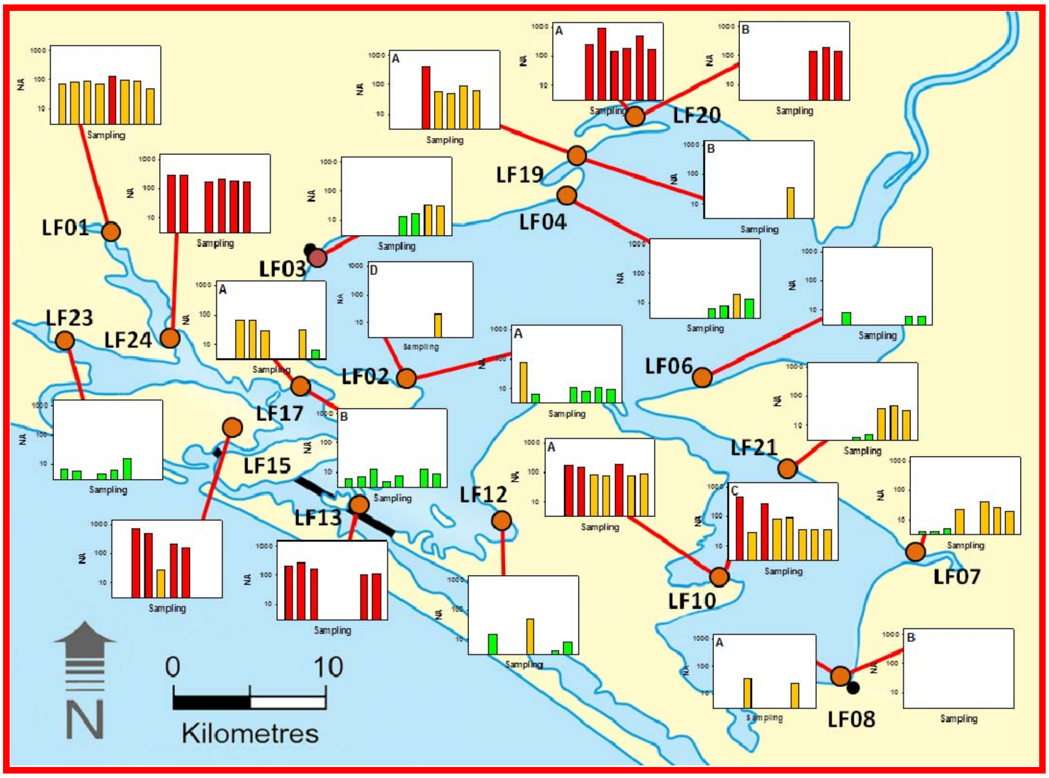


Figure 3-23. NA of surface sediment as a function of time/sampling from various study areas around the Lower Lakes. Each plot comprises up to eight vertical bars that represent soil NA (Green: 0 to 19 mol H^+/t, orange: 19 to 100 mol H^+/t, red: > 100 mol H^+/t) for each of the eight sampling occasions between August 2007 and February 2013. **Note:** Only positive NA is plotted because the Y-axis is a log scale from 3 to 1500 mol H^+/t.

In the **middle** of the soil profile, the highest NA values were located on the northern margin of Lake Alexandrina (LF03, LF19 and LF20), in the Finniss River (LF01 and LF24) and on the northern side of Lake Albert (LF07 and LF21; Figure 3-24). The high NA on the northern side of Lake Alexandrina and in the Finniss River comprised significant quantities of CRS, RA and TAA (Figure 3-12, Figure 3-15 and Figure 3-18). In contrast, the high NA on the northern side of Lake Albert were dominantly associated with CRS (Figure 3-12). This was probably because water levels were maintained at a higher level for longer in Lake Albert (Figure 1-1; compared to Lake Alexandrina) and oxidation and subsequent acidification did not penetrate as deep in to the profile (Section 3.3).

Elsewhere in the Lakes, much lower NA levels (and TAA: Section 3.6) were associated with soil material from the middle of the profile. Generally, these soil layers were dominated by sand (Section 3.2) with lower overall acid generating potential (i.e. NA: Section 3.9). However, it should be noted that even though these layers had comparatively low NA levels, they were still subject to acidification during drought, probably because of the poor buffering capacity of sand, and in some instances, took a long time to neutralise (Section 3.3).

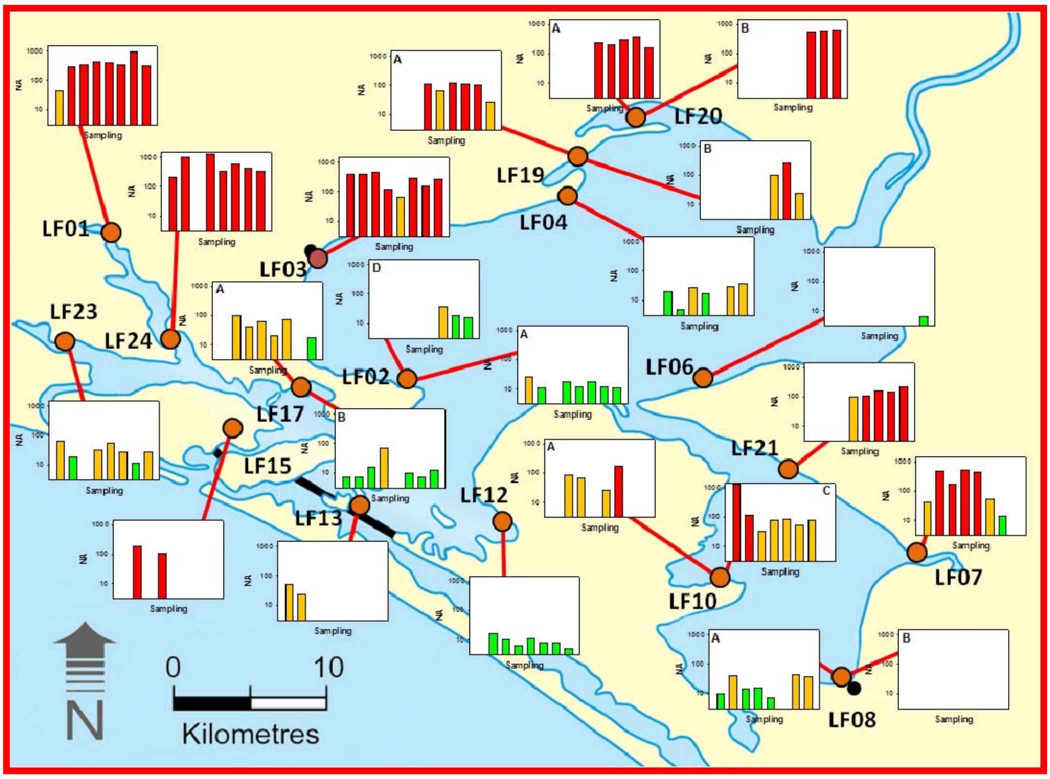


Figure 3-24. NA of sediments from the middle of the soil profile (30 to 50 cm) as a function of time/sampling from various study areas around the Lower Lakes. Each plot comprises up to eight vertical bars that represent soil NA (Green: 0 to 19 mol H^+/t, orange: 19 to 100 mol H^+/t, red: > 100 mol H^+/t) for each of the eight sampling occasions between August 2007 and February 2013. **Note:** Only positive NA is plotted because the Y-axis is a log scale from 3 to 1500 mol H^+/t.

The highest NA was generally found in soil material from the **bottom** of the profile (Figure 3-25). This is most likely related to soil texture, as many of the study sites that were investigated around the Lower Lakes comprised sand overlying medium to heavy clay at the base of the profile (Section 3.2). These clays often contained significant CRS concentrations with an equivalent of more than 500 mol H^+/t that contributed much of the potential acidity to the elevated NA (Section 3.5). Although many of these sediments also contained significant quantities of ANC, this was often insufficient to neutralise the potential acidity store (Section 2.8).

Elevated concentrations of CRS contributed to high NA (Figure 3-25) in sediments from the bottom of the profile, which present a significant risk of acidification during extreme drought scenarios. This was demonstrated by pH incubation experiments that indicated that many of these basal sediments have the potential to become sulfuric (pH < 4) when dried (Section 3.4).

A few sites had negative NA, even though they contained very high concentrations of CRS (e.g. LF13, LF19-A and LF19-B; Section 3.5). This was because the elevated CRS was accompanied by sufficient concentrations of ANC to neutralise the potential acidification hazard (Figure 3-22). Thus, incubation experiments indicated that these layers were unlikely to acidify during future drought scenarios (Figure 3-10).

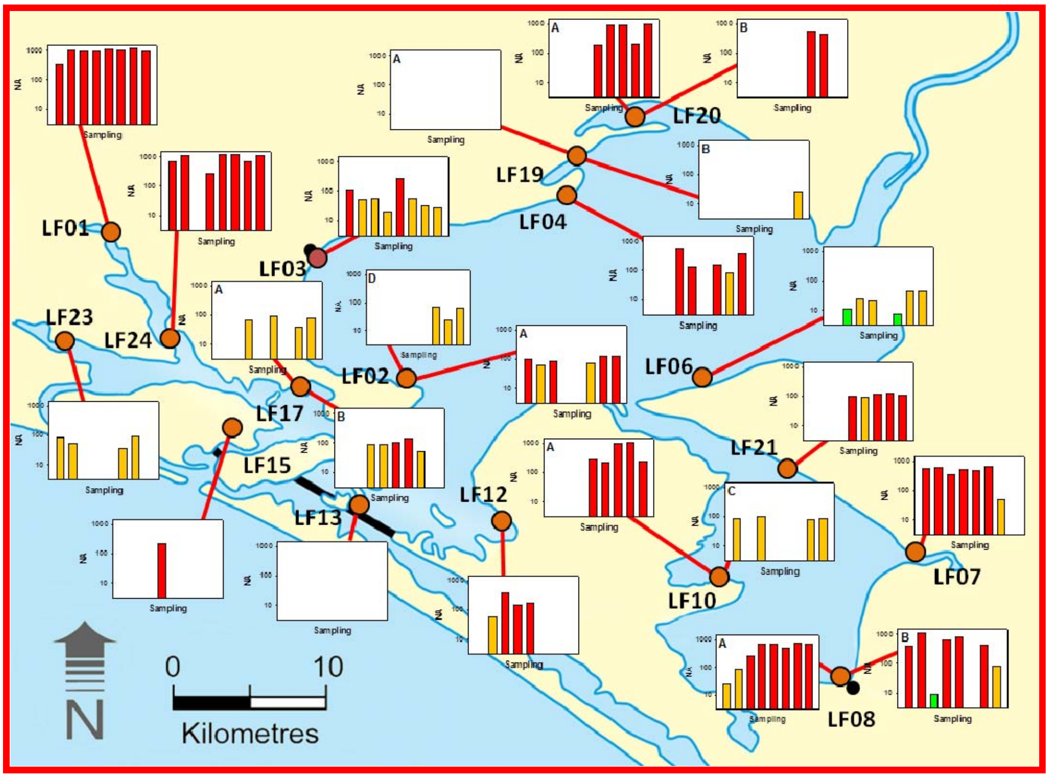


Figure 3-25. NA of sediments from the bottom of the soil profile (> 60 cm) as a function of time/sampling from various study areas around the Lower Lakes. Each plot comprises up to eight vertical bars that represent soil NA (Green: 0 to 19 mol H^+/t, orange: 19 to 100 mol H^+/t, red: > 100 mol H^+/t) for each of the eight sampling occasions between August 2007 and February 2013. **Note:** Only positive NA is plotted because the Y-axis is a log scale from 3 to 1500 mol H^+/t.

4. DISCUSSION

The River Murray is a highly managed system and water levels in the Lower Lakes have been maintained via a series of upstream locks and coastal barrages separating it from the saline lagoons of the Coorong. The Millennium Drought (2000 to 2010) in south-eastern Australia had its most severe impact on soil acidification from 2007 to 2010 when low inflows caused a rapid decline in water levels to around -1 m AHD in Lake Alexandrina (Figure 1-1), the lowest levels recorded since introduction of the locks and barrages in the 1930's – 1940's. Water levels declined less in Lake Albert due to the building of a bund between the Lakes and topping up of Lake Albert from Lake Alexandrina (DENR 2010).

Very high evaporation rates during the drought combined with low inflows and shallow water depth, caused large expanses of previously sub-aqueous soil to become exposed along the margins of the lakes. This section provides a summary of the key findings associated with monitoring the soils from a baseline condition through the drought and subsequent recovery of water levels. The drought ended with very high sustained inflows to many wetlands along the River Murray including the Lower Lakes (Figure 1-1). The following sections provide a summary of the main impacts of the drought on acidity hazards, the response and recovery of soils to renewed inflows, the current state of play and implications for future periods of drought.

4.1 The current state of play

Soil pH conditions were highly variable during and after the drought and were dependent on locality, soil texture and depth within the profile. By the end of the monitoring period, in February 2013, soil material around the margins of the Lower Lakes had been inundated for more than 2 ½ years.

In surface soils, pH was greater than 5.5 at 17 of the 23 monitoring sites (i.e. green cells: Figure 4-1). What little ANC was present in surface soils was generally associated with sites that had pH values above 5.5 (Figure 4-2).

At six sites, all located in Lake Alexandrina, surface sediments remained relatively acidic with pH values between 4 and 5.5. The surface sediments from Dog Lake (LF20-B) were clay rich (Figure 3-3) with high NA (> 100 mol H^+/t; Figure 4-3) that comprised significant quantities of TAA with minor RA (Figure 4-5). In contrast, the surface sediments from the remaining acidic sites at Dog Lake (LF19-A), Milang (LF03) and Point Sturt (LF02-A and LF17-B) comprised sandy soil material (Figure 3-3) with lower NA (10 to 60 mol H^+/t; Figure 4-3) that was dominated by TAA with no RA (Figure 4-5). Although these soil were broadly categorised as sands (Figure 3-3), they did contain silt, loam or clay as minor constituents (Appendix A). This meant that, compared to other sandy sites, acidity in surface soils at these locations was probably less easily flushed from the system following inundation, which maintained lower pH conditions.

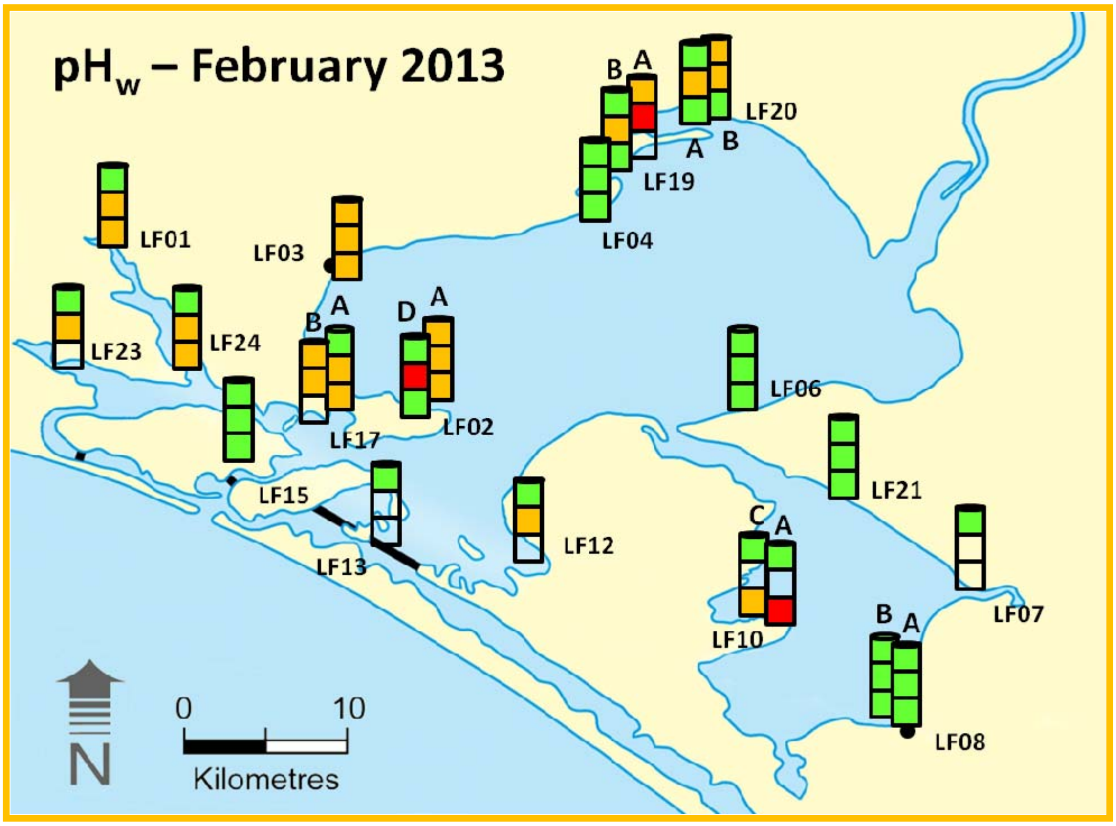


Figure 4-1. pH of sediments in February 2013 (last sampling). Each plot comprises three stacked cells that represent soil pH in the top (< 20 cm), middle (30 to 50 cm) and bottom (> 60 cm) of the soil profile (red: pH < 4, orange: pH 4 to 5.5, green: pH > 5.5). Where cells have no fill, soil layers were not present or not able to be adequately identified.

In contrast to surface sediments, lower pH conditions persisted longer in soil material from the middle of the profile (Figure 4-1). After more than 2 ½ years of inundation, soil pH conditions of less than 5.5 persisted at 13 of the 19 monitoring sites (that were sampled) and sulfuric materials (pH < 4) were still present at Point Sturt (LF02-D) and Dog Lake (LF19-A).

Sediments from approximately half of these sites consisted of clayey material (Figure 3-3) with high NA (Figure 4-3) that comprised significant quantities of TAA and RA (e.g. LF01, LF03, LF19-B, LF20-A, LF20-B and LF24; Figure 4-6). Little or no ANC was present in these soil layers (Figure 4-2).

Seven sites, with acidic middle sediments, were broadly categorised as sands (Figure 3-3) but contained silt, loam or clay as minor constituents (e.g. LF02-A, LF02-D, LF12, LF17-A, LF17-B, LF19-A and LF23; Appendix A). These had little or no ANC (Figure 4-2) and relatively low NA ranging from approximately 5 mol H^+/t to 30 mol H^+/t (Figure 4-3). Initial drought induced acidification of these layers was most likely exacerbated by a lack of mineral buffering in relatively unreactive quartz-rich sands. Persistence of relatively low pH conditions (until at least February 2013) was most likely related to soil texture (i.e. minor silt, loam and sand) and depth in the profile that meant that only limited flushing of acidity occurred following inundation.

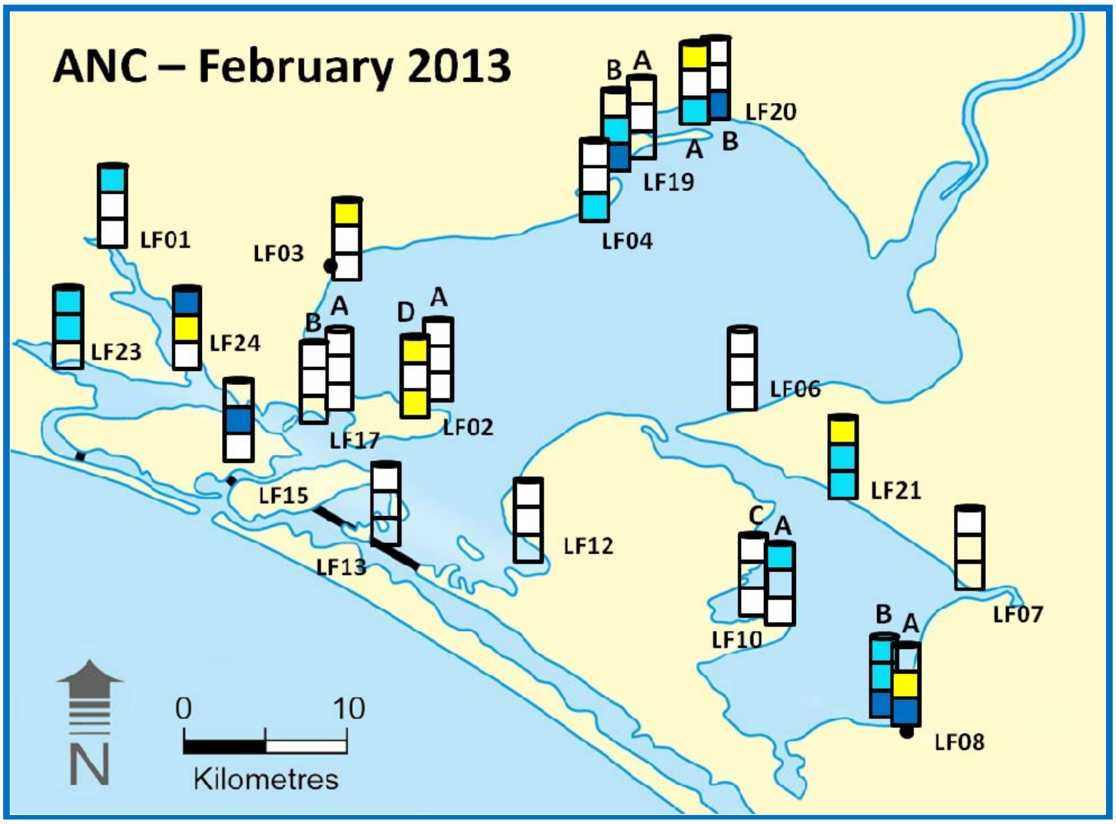


Figure 4-2. ANC of sediments in February 2013 (last sampling). Each plot comprises three stacked cells that represent soil ANC in the top (< 20 cm), middle (30 to 50 cm) and bottom (> 60 cm) of the soil profile (White: = 0 mol H^+/t , Yellow: < 28.5 mol H^+/t, cyan: 28.5 to 150 mol H^+/t, blue: > 150 mol H^+/t). Where cells have no fill, soil layers were not present or not able to be adequately identified.

In soils from the bottom of the profile, pH was greater than 5.5 at 10 of the 17 monitoring sites that were sampled (i.e. green cells: Figure 4-1). These sediments generally experienced less acidification and higher pH both during and after the drought. This was most likely because they were below the maximum depth of oxidation that occurred during the drought.

Generally, there was more ANC present at the bottom of profiles compared to the middle and surface layers (Figure 4-2). This was most likely because many of these layers were beyond the maximum depth of drought induced oxidation and because they comprised medium to heavy clays (Section 3.2) that contained higher initial (pre-drought) amounts of ANC.

The highest NA was generally found in soil material from the bottom of the profile (Figure 4-3). This is most likely related to soil texture, as many of the study sites that were investigated around the Lower Lakes comprised sand over clay (Section 3.2). These clays often contained significant CRS concentrations with an equivalent of more than 500 mol H^+/t that contributed much of the potential acidity to the elevated NA (Section 3.5). Although many of these sediments also contained significant quantities of ANC, this was often insufficient to neutralise the potential acidity store.

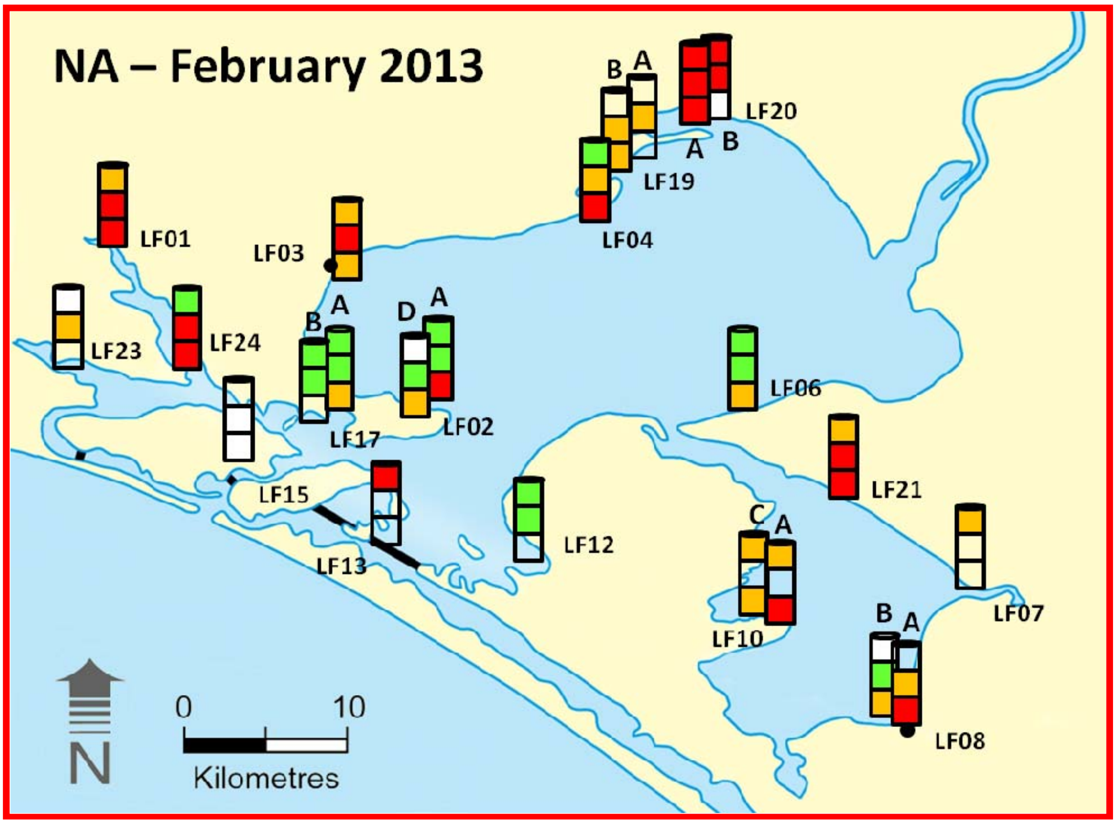


Figure 4-3. NA of sediments in February 2013 (last sampling). Each plot comprises three stacked cells that represent soil NA in the top (< 20 cm), middle (30 to 50 cm) and bottom (> 60 cm) of the soil profile (White: < 0 mol H^+/t, green: 0 to 19 mol H^+/t, orange: 19 to 100 mol H^+/t, red: > 100 mol H^+/t). Where cells have no fill, soil layers were not present or not able to be adequately identified.

4.2 What was the overall impact of drought on acidification of marginal soils of the Lower Lakes?

The low inflows combined with high evaporation led to exposure of sub-aqueous soils and a deepening oxidation front. Soil acidification was extensive around the lake margins with soil materials commonly becoming sulfuric (pH < 4). A number of studies in the Lower Lakes have also highlighted the management of soil acidification during the drought (see DENR 2010 for summary). Other studies have highlighted the impact of oxidation on the release mobilisation of soil contaminants such as metals and metalloids (Shand *et al.* 2012).

The median and interquartile ranges of soil pH remained low over the drought period (Figure 2-3). The large volumes of inflows had a significant effect on soil pH and a much higher median was measured during sampling c within a few months of higher water levels (Figure 1-1, Figure 2-3). However, the range of pH values remained much higher than the pre-drought baseline as some soil layers remained acidic throughout the monitoring period to February 2013. The recovery period is thus much longer than the acidification phase which occurred very rapidly.

The summary data (Chapter 2) also highlighted a decrease in median CRS and ANC along with an increase in TAA and RA. The statistical data also highlight that, for none of the measured parameters, has there been a return to pre-drought conditions despite re-inundation over several years. The average incubation pH and NA do not appear to have changed overall, but of some concern is the loss of ANC in some samples which is the first line of defence in neutralising acid generated during the oxidation of sulfide minerals. This may mean that, for these samples, future oxidation events occur more rapidly and that impacts may be more severe during limited oxidation.

The impacts were thus widespread, but notable is the orders of magnitude variability indicated by the range of values in these key parameters as a consequence of heterogeneity at a range of scales.

4.3 How much variability was there in acidification impacts across the Lakes?

The data for all measured and characterised parameters highlights the large degree of spatial variability at a range of scales (cm to km) both geographically and with depth. In terms of soil texture, many of the sites at the margins of the Lakes comprised sand over clay, however, the depth to the clay layer varied significantly, and in some cases the profiles were entirely sandy. A significant number of sites also comprised clay throughout the profile or organic matter over clay or sand (Figure 3-3). Calcrete was also encountered at surface and shallow depth in some areas beneath sands e.g. between Waltowa and Meningie. It is in this heterogeneous marginal interface that oxidation of the soils took place.

Soil texture plays an important role in determining the degree of hazard and also the response to movement of acidity during both the oxidation and subsequent recovery. During the initial stages of drying the sandy soils were rapidly impacted especially where there was significant sulfide and little ANC. This is both a function of high permeability and limited buffering in the sands.

The formation of thin acid-storing minerals layers such as sideronatrite were observed as crusts on sulfuric sands as water levels initially fell, particularly during the summer period when capillary effects were dominant. Although the total amount of acidity was often less than in clay soils, there was sufficient acidity to impact water (e.g. a pH of 4 represents 10^{-4} moles/litre, a fraction of the amount of acidity stored in most of the sandy soils). Following rainfall events, however, the pH of many of the sulfuric surface soils increased as the relatively small amount of acidity (compared to clays) was washed into the permeable sands. This acidity was either transported deeper in the profile, possibly neutralised at depth, or transported laterally towards the lake once it reached saturated zone (early observations e.g. at Waltowa where orange-brown patches were observed in places close to the Lake shore). The spatial and temporal variably of acidification impacts is highlighted on maps shown in Chapter 3. These variations are related to degree of oxidation, soil type, acidity stores and amount of ANC. The differences between sites are large, but also noticeable is the variations along transects and within profiles. Previous spatial work at Waltowa and Browns Beach north of Meningie also confirmed the high variability in ASS characteristics at the m to 10’s m scale in sands.

The degree of heterogeneity at a local scale in the clays was very large. Cracking was a ubiquitous feature of the dried clays with a range of cracking styles and widths. The surfaces of peds and along smaller cracks were often dominated by coatings of natrojarosite where oxidation combined with capillary effects was most extensive. In many samples, there was incomplete oxidation of sulfide within peds highlighting, therefore, extreme chemical disequilibrium (pyrite and natrojarosite are not stable together). Although the clays provide more buffering in general than the sands, CRS contents were often very high. Retained acidity in the form of natrojarosite was found to remain in many soils for months to years after inundation helping to maintain low pH by slow dissolution rates. This was exacerbated by the low permeability of the clays. Even in areas where sands occur at the surface, capillary effects from the clays could keep overlying sands acidic by providing a constant source of acidity. The variations within the clays for most ASS measurements were very large as shown on the maps in Chapter 3.

The scale of heterogeneity in both sands and clays makes the development of predictive models based on actual reaction and transport processes difficult as most incorporate bulked parameters. Nevertheless, a number of hot spots were identified in some parts of the lakes where high NA and incubation pH were consistent (e.g. Dog Lake: LF19, Boggy Lake: LF20, Campbell Park: LF10, Finniss River:LF01/LF24 and the northern side of Lake Albert LF07/LF21) in determining high hazard potential, that will be useful in remedial actions prior to and following high water level recovery.

4.4 What was the variability in rate of recovery from acidification across the lakes following the end of the Millennium Drought?

The time series maps are extremely useful in assessing how the different sites have responded since the end of the drought period. The data highlight that recovery was variable at a regional scale, and also at a very local scale (cm to m). The rates of change were not linear at any scale, but this is to be expected since the change is linked to buffering mechanisms in the soils. The buffering capacity by solution alkalinity or soil ANC is well known, and changes in pH can change rapidly depending on the presence or loss of carbonate minerals/alkalinity. In a similar way, acidity can be buffered by the presence of acid generating minerals and relevant to the Lower Lakes is the formation of jarosite (measured as RA) and other forms of stored acidity such as TAA. The rates of recovery for different areas is thus controlled by the distribution of acidity vs. ANC.

Since reactions are catalysed by water as a medium, the permeability and transport of water (and solutes) is key to understanding how impacted systems will respond. Rate of recovery is partly linked to texture: clays are less easily flushed and tend to have higher sulfide contents and NA. Where sand dominated the soil profile, TAA was rapidly flushed out of the sediment following inundation. The rate of recovery is largely determined by the quantity and type of acidity in the system. Readily available acidity (TAA) is highly reactive, but can more easily be flushed from the system especially from sandy sediments.

During the early stages of inundation, it was frequently observed that both yellow jarosite mottles and black sulfidic patches were present in the re-saturated soils. Such conditions lasted for some time at many sites. This indicates extreme disequilibrium, and highlights that recovery from acidification was relatively rapid at a local scale. This scale of heterogeneity may pose some problems for the standard toolbox used for soil analysis e.g. acid-base accounting as the scale is smaller than sample sizes needed for analysis and the data will represent an average of the soil. Nevertheless, combined with field observations and monitored change, the data provide trends for the timing of recovery. The black mottles were typically associated with organic matter, which is an important master variable in controlling the redox potential, making conditions viable for reduction (and alkalinity generation). The slow dissolution of jarosite means that this mineral may buffer the soils at low pH for long periods of time and, therefore, the local rates of recovery may be much slower. This is particularly the case in clay soils with higher RA and low permeability.

At the soil profile scale, there were large vertical changes in neutralisation of acidity. Recovery was more significant in the upper soil layers, and often the middle layers remained acidic. The reasons for this are several fold:

- Higher labile organic matter in surface soils, which support reduction processes and the consequent generation of alkalinity.
- Infiltration during refilling of fresh surface water generating a downward flux of acidity and contaminants from the surface layers.
- For heavy textured soils, the diffusive fluxes of acidity from the sediment to the overlying water and the reverse for alkalinity.
- The common occurrence of more sandy sediments at the surface.

Incubation experiments combined with acid-base accounting (ABA) show that there has been little or no loss of acidity (actual or stored) from the soils, although some data suggest some local transport at the cm scale e.g. flushing of acidity downwards through the profiles in sands. For the sands, however, sulfides are now beginning to form in surface layers. The stores of actual and potential acidity have simply been cycled within the soils.

The deeper soil layers in some cases did not oxidise significantly and returned to reducing conditions relatively rapidly. In a few cases, where oxidation was more significant, they have remained acidic due to acid buffering by jarosite.

The slowest recovery was typically in the middle of the profile, and throughout the monitoring it was commonly found that acidic soil materials were sandwiched between less acidic upper and lower layers. The acidic buffering capacity of the middle layers was spatially variable with an increase in pH taking place at different times during the monitoring period. There is a tendency for slower recovery where sands are more silty suggesting that transport is a limiting factor as well as potentially more stored reactive forms of acidity (TAA + RA).

Although the middle soil layers continue to pose a hazard from acidity and contaminants such as metals and metalloids, they are often overlain by a higher pH sulfidic reducing layer and a thin oxidised top layer. These layers form a chemical barrier between acidic soils and the overlying surface water limiting any diffusional flux upwards. In some cases, this upper layer is thin and there is therefore potential for this to be lost if water levels decrease in the future. The soils are thus in a transient state with recovery varying spatially and with time.

4.5 How did acidity pools change with time and what were the dominant controls on soil recovery and the neutralisation of acidity?

The detailed chemical analysis and measurements of acid sulfate soil characteristics over time has allowed a much better picture to be developed not only of the timescales of recovery and their regional variations, but also on the transformations of stored and actual acidity and rates of change over time. In order to visualise these changes, a series of maps have been produced showing the relative proportions of the components of acid-base accounting. These have been normalised to 100%, and should be used in conjunction with absolute concentration maps shown previously in Chapter 3.

During oxidation of a soil with significant sulfide and little ANC, one would expect to see a change from sulfide dominated (CRS) sub-aqueous conditions to the formation of TAA as acidity is produced (Figure 4-4). Further oxidation will lead to the formation of natrojarosite if pH falls sufficiently and RA will then be present. During Recovery, natrojarosite will likely buffer the pH at low values until the jarosite is consumed/reduced. Further neutralisation is likely to occur with infiltration of alkalinity bearing waters and the onset of reduction reactions (particularly Fe^{3+} and SO_4 reduction). The system may then return to a sulfide dominated system with sufficient time. A real example from the middle of the soil at (LF02) is plotted in Figure 4-4, illustrating the general principle. In this example, the system has not yet returned to a baseline state.

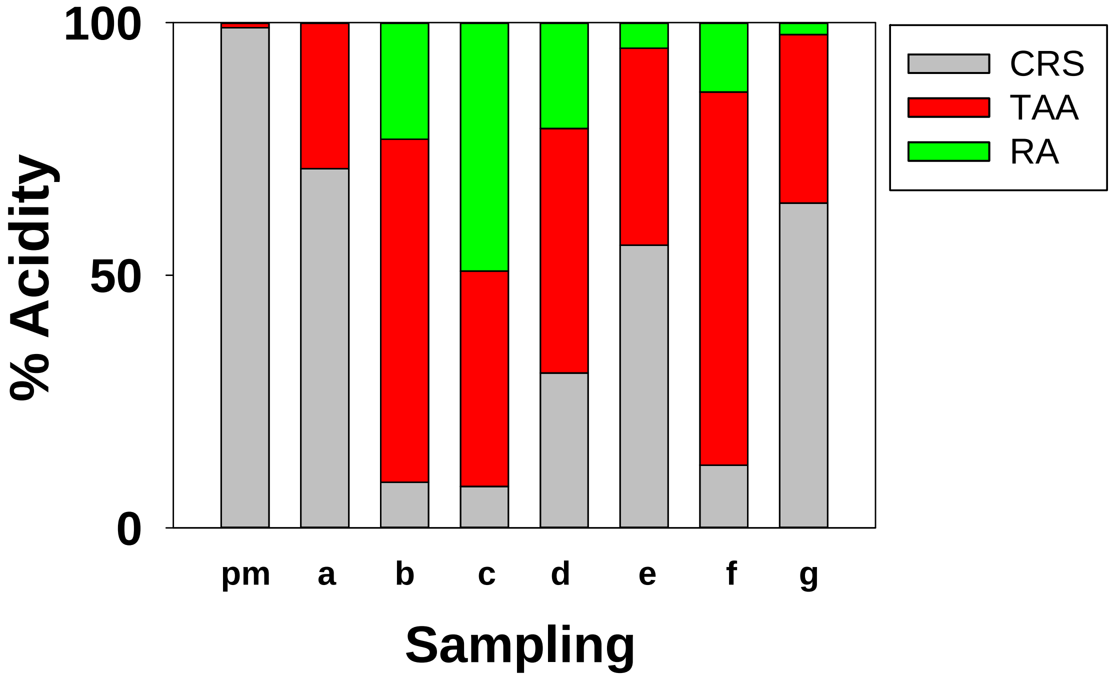


Figure 4-4 Acidity types, normalised to 100%, within an example from the middle soil layer at Milang (LF03) as a function of time/sampling. The plot comprises eight vertical bars (grey: CRS fraction, red: TAA fraction, green: RA fraction) for each of the eight sampling occasions between August 2007 and February 2013.

Data for the **surface** soil layers are shown in Figure 4-5. During the drought, all of the surface soil layers dried and oxidised. Almost all surface layers showed evidence of soil acidification in the form of increased TAA and RA, but some samples contained sufficient ANC or low NA, such that any acidity generated was neutralised (e.g. LF08 Meningie). The degree of acidification varied spatially and not all samples acidified enough, or there was a limiting component, to form natrojarosite, which meant RA did not form in significant quantities during the drought. In many surface soils, TAA remained present throughout the monitoring period but the amount was variable across the lakes. For some soils, TAA remained high despite a return to circumneutral pH. This may be a consequence of the presence of reduced metal species or organic acids in solution or weakly sorbed to the soils.

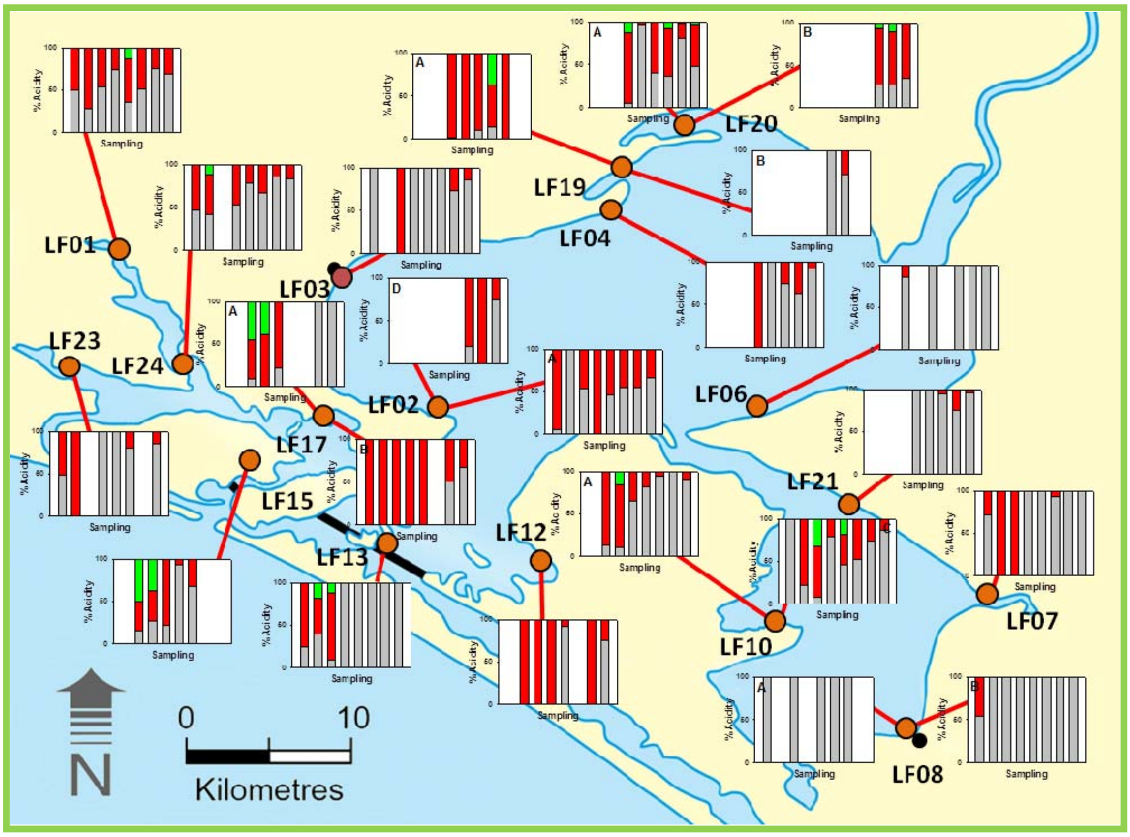


Figure 4-5. Acidity types, normalised to 100%, within surface sediments as a function of time/sampling from various study areas around the Lower Lakes. Each plot comprises up to eight vertical bars that represent the total acidity in each sample (grey: CRS fraction, red: TAA fraction, green: RA fraction) for each of the eight sampling occasions between August 2007 and February 2013.

Soils from the **middle** of the profile are shown in Figure 4-6. There is generally a similar pattern to the surface soils, however, the presence of TAA and particularly RA shows that recovery has been much slower in the middle layers. This is consistent with the typically higher NA and presence of natrojarosite in many of these soils.

The persistence of RA in sandy soils is also likely to be a function of less flushing following initial infiltration. Where this occurred, sandy soils generally contained minor silt, loam or clay that would have made them much less permeable. For Loveday Bay (LF12), where surface waters acidified, the role of constricted flows in such areas with poorer connectivity to the main lake has also played a role that limited recovery. Monitored sites with clay as the dominant soil type were present mainly in the west and north of Lake Alexandrina and the high contents of RA have limited the recovery of acidification in these less permeable soils.

Where the most severely impacted soils persist, the risk to the surface water is considered less where they are overlain by a moderately thick reducing surface soil with higher pH. This will act as a barrier (and buffer) to the upward diffusional flux of acidity and metals. A comparison of the middle and upper layers suggests that areas such as Dog Lake and Boggy Lake pose the greatest threat to acidification of surface waters or contaminant fluxes to surface water.

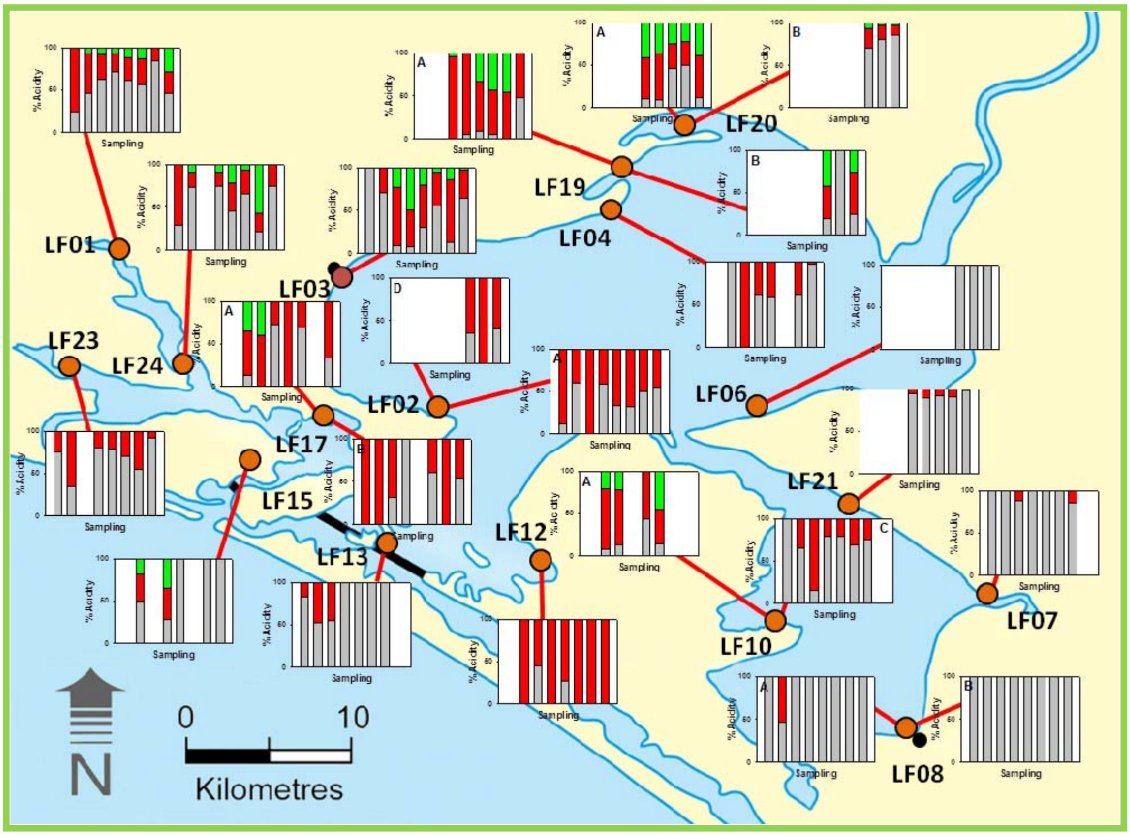


Figure 4-6. Acidity types, normalised to 100%, within sediments from the middle of the soil profile (30 to 50 cm), as a function of time/sampling from various study areas around the Lower Lakes. Each plot comprises up to eight vertical bars that represent the total acidity in each sample (grey: CRS fraction, red: TAA fraction, green: RA fraction) for each of the eight sampling occasions between August 2007 and February 2013.

The **bottom** soil layers are dominated by stored acidity in the CRS fraction (Figure 4-7). This was often because these samples being below the oxidation front during the drought. For others sites, the oxidation front reached the deeper layers sampled and sulfide oxidation led to the development of sulfuric soils. The pattern of acidification leading initially to TAA and then RA, followed by a decrease in loss of RA is also apparent in the impacted deeper soils. Several sites still contain high TAA and for one of the sites at Campbell Park (LF10-A) significant RA due to buffering from natrojarosite.

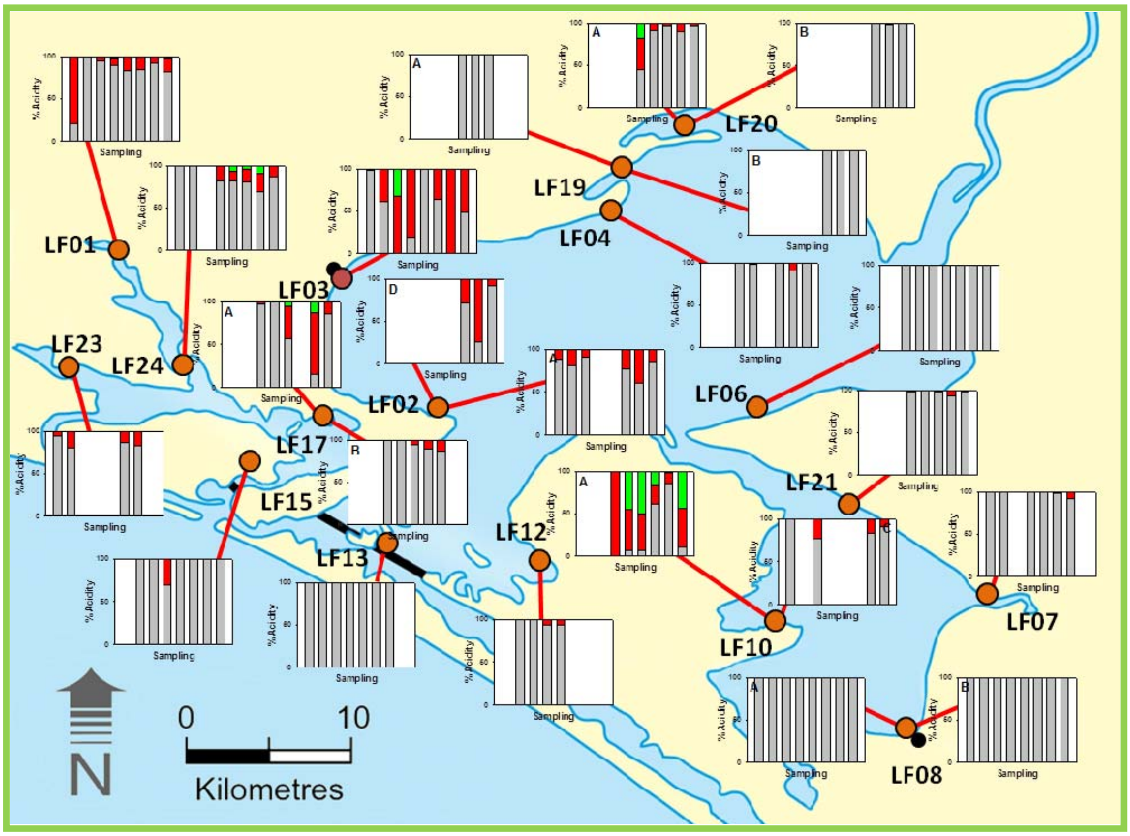


Figure 4-7. Acidity types, normalised to 100%, within sediments from the bottom of the soil profile (> 60 cm), as a function of time/sampling from various study areas around the Lower Lakes. Each plot comprises up to eight vertical bars that represent the total acidity in each sample (grey: CRS fraction, red: TAA fraction, green: RA fraction) for each of the eight sampling occasions between August 2007 and February 2013.

The normalised acidity type plots show a consistent pattern of varying degrees of transformation of CRS to TAA followed by RA, but this is very heterogeneous across the lakes. The impact was less in Lake Albert where water levels were artificially increased by pumping and had a shorter period of oxidation. In general, recovery has been greater in the surface soils and at depth, whilst the middle layers have been slower to recover.

4.6 What could have happened and what might happen next?

The data presented in this report has provided a critical evaluation of the impact of drought on marginal sub-aqueous soils through the exposure and oxidation of sulfide minerals. It also provides key data on the rates of recovery following inundation after the end of the Millennium Drought. The timescale of recovery was much longer than previously anticipated by scientists and managers (i.e. > 4 year; Figure 4-9), indeed the system is still in a transient state of recovery to pre-drought conditions after several years of high lake water levels. The volume and sustained delivery of high inflows provided a best possible scenario, helping to lessen severe impacts on surface water by minimising stagnation, providing added alkalinity and by providing a high head to limit any initial upward flux and release of contaminants (2 → 3a; Figure 4-9). Several areas of surface water around the lake displayed a decrease in alkalinity, but a complete loss of alkalinity and loss of buffering only occurred in a few areas (DENR 2010). Although the recovery of surface soils in many areas appeared to be rapid, many subsurface soils took much longer to undergo acid neutralisation, and indeed some remain acidic (February 2013; 4a: Figure 4-9). Therefore, even in this best possible scenario, with water levels and flow through the lakes remaining high, the impacts on soil have been significant.

Two important questions to consider are, therefore: has the system improved, since the Millennium Drought, due to the previous drying and oxidation?; and what will be the impact of future droughts? The latest pH incubation data (Figure 4-8) helps to answer these questions.

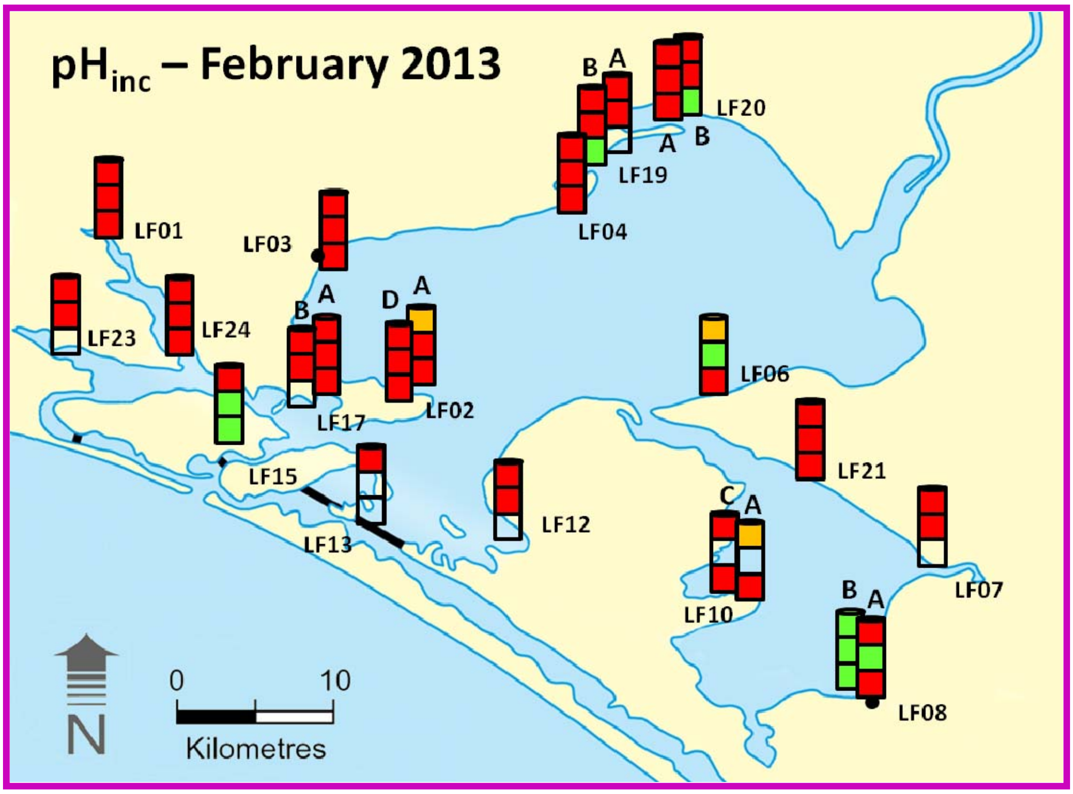


Figure 4-8. PH$_{inc}$ (> 10 weeks incubation) in February 2013 (last sampling). Each plot comprises three stacked cells that represent soil pH in the top (< 20 cm), middle (30 to 50 cm) and bottom (> 60 cm) of the soil profile (red: pH$_{inc}$ < 4, orange: pH$_{inc}$ 4 to 5.5, green: pH$_{inc}$ > 5.5). Where cells have no fill, soil layers were not present or not able to be adequately identified.

The data clearly show that there has been little overall change in the potential of the soils to acidify, and this has been consistent throughout the monitoring period. Although the pH has increased since the end of the drought (Figure 4-9), the acidity has simply been removed and stored in mineral phases such as pyrite, which can easily be re-oxidised/mobilised. The message is thus clear that there has been relatively little loss in overall actual or potential acidity during flow through the lakes. The chemistry of Fe and S, which are responsible for sulfide formation, have simply been cycled in the soils with no net change at relevant scales, hence little change in hazard or risk over time.

The kinetics of change were not studied in detail, but the laboratory incubation periods were short and show that oxidation is rapid. There is a possibility that the impact of future droughts in the near future may be more rapid. Firstly, it is known that some newly formed minerals have higher reaction kinetics, which slows over time as they ‘age’. Secondly, there has been a loss of ANC from some parts of the system (Figure 2-9). Although there would have been a similar decrease in acidity, the loss of carbonate would mean that the initial buffering might be lost and the onset of acidification might be more rapid.

Future drought scenarios will likely see a rapid return to the acidified soil conditions of the Millennium Drought (Figure 4-9). Additionally, if water levels return more slowly than occurred following the Millennium Drought, there is the potential for:

- greater decreases in surface water alkalinity,
- the complete loss of alkalinity and buffering in more areas
- and acidification of stagnant, ponded water bodies around the margins of the Lakes.

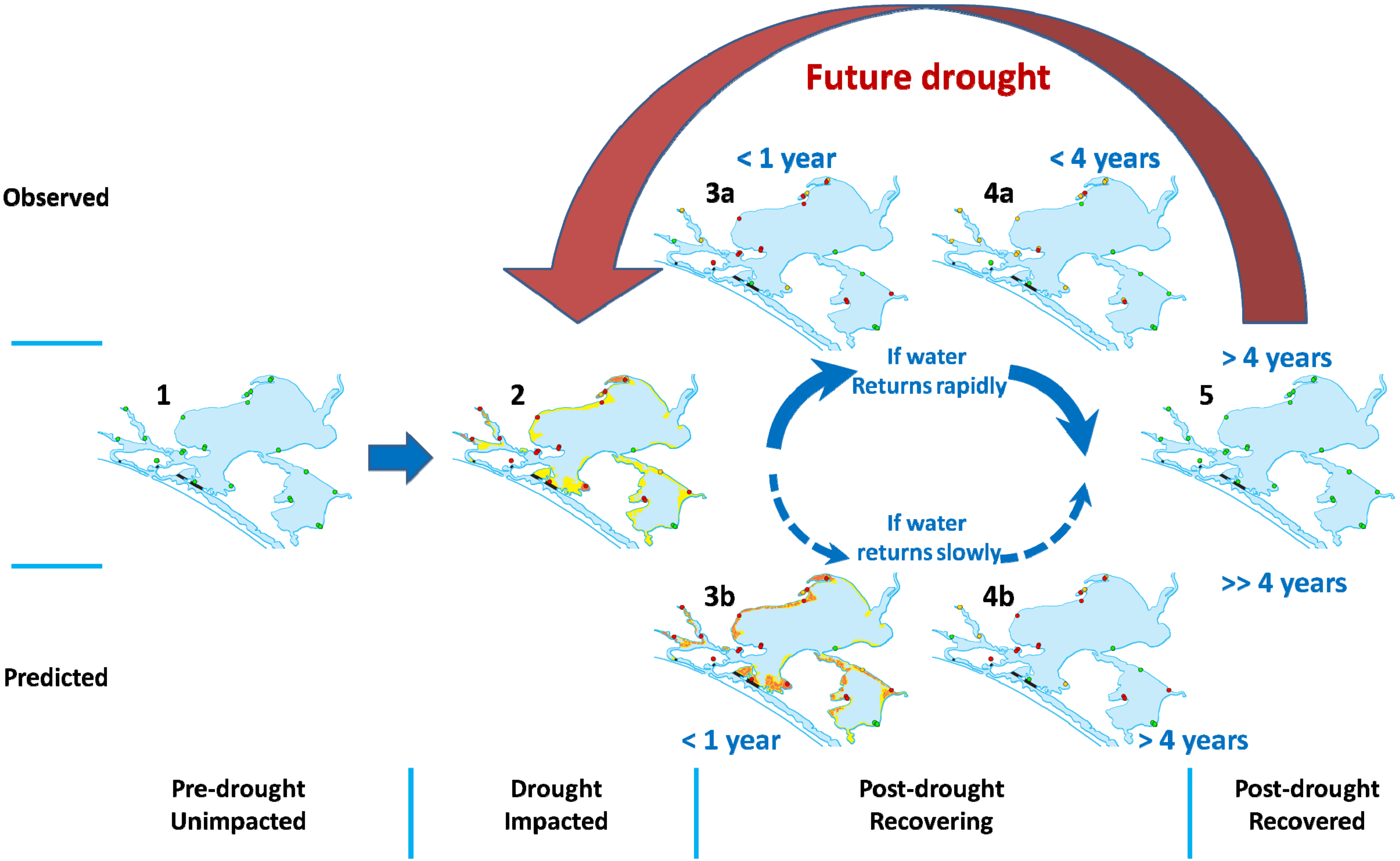


Figure 4-9. Observed and predicted impacts of soil and surface water acidification as a function of pH. Coloured dots represent minimum soil pH conditions within 1 m of the surface (red: pH < 4, orange: pH 4 to 5.5, green: pH > 5.5). Yellow shading indicates exposed lakebed under drought conditions. Red shading indicates actual or predicted pools of acidified surface water. Conditions observed before, during and after the Millennium Drought, when water levels increased rapidly at the end of 2010, follow the path 1 → 2 → 3a → 4a → 5a (predicted). Predicted conditions, which may occur if water levels had returned more slowly, follow the path 1 → 2 → 3a (predicted) → 4a (predicted) → 5a (predicted).

5. CONCLUSIONS

- The median soil pH in the Lower Lakes prior to the drought was circumneutral and displayed a narrow range.
- The median and interquartile ranges decreased significantly during the drought.
- The impact of drought induced soil acidification along the margins of the Lower Lakes was very variable. This largely relates to heterogeneity of the soil types and acid sulfate soil parameters as well as geomorphological controls.
- The median pH increased significantly when sustained high flows returned in late 2010, however, many of the soils remained acidic up to the end of the monitoring period (2013).
- The rates of recovery over time were complex and did not change linearly. Rates also varied spatially and with depth highlighting a highly heterogeneous system.
- The impact of acidification is different for sandy soils compared to clay soils. Marginal sands (mainly unreactive quartz grains) tend to have a more rapid impact due to little mineral buffering, but often contain less total acidity than clays and can be more easily flushed due to higher permeability.
- Rate of recovery is partly linked to texture: clays are less easily flushed and tend to have higher sulfide contents and NA. Where sand dominated the soil profile, TAA was rapidly flushed out of the sediment following inundation.
- The slowest recovery was typically in the middle of the profile, and throughout the monitoring it was commonly found that acidic soil materials were sandwiched between less acidic upper and lower layers.
- The rate of recovery is largely determined by the quantity and type of acidity in the system. Readily available acidity (TAA) is highly reactive, but can more easily be flushed from the system especially from sandy sediments.
- The slow dissolution of jarosite means that this mineral may buffer the soils at low pH for long periods of time and, therefore, the rates of recovery will be much slower. This is particularly the case in clay soils with higher CRS and low permeability.
- Sulfide contents decreased during the Millennium Drought, and although some reformed following inundation, in many cases concentrations were less than originally present (e.g. Campbell Park). Soils are in a transient state and the build-up of sulfide is likely to continue under saturated conditions.
- The form of acidity is changing over time. A general ‘ideal’ sequence during soil recovery for acid sulfate soils systems is:
    - Acidity generated from jarosite will buffer the system to low pH (production of TAA) until consumed maintaining TAA.
    - Neutralisation of TAA as alkalinity is generated, mainly by neutralisation and reduction processes (O, NO_3, Mn, Fe).
    - Formation of reduced S species leading the formation of sulfide minerals which acts as a store of acidity.
- Recovery was more significant in the upper soil layers, and often the middle layers remained acidic. The reasons for this are several fold:
    - Higher labile organic matter in surface soils which support reduction processes and the consequent generation of alkalinity.

  - Infiltration during refilling of fresh surface water generating a downward flux of acidity and contaminants from the surface layers.
  - The common occurrence of more sandy sediments at the surface.

- Incubation experiments combined with acid-base accounting (ABA) show that there has been little or no loss acidity (actual or stored) from the soils, although some data suggest some local transport at the cm scale e.g. flushing of acidity downwards through the profiles in sands. For the latter, however, sulfides are now beginning to form in surface layers. The stores of actual and potential acidity have simply been cycled within the soils.

- Soil pH levels in many areas have not returned to pre-drought levels and acidification hazard remains high in many parts of the lakes.

- The onset of future acidification may be more rapid in areas where ANC has been lost.

- If water levels return more slowly than occurred following the Millennium Drought, there is the potential for:
  - greater decreases in surface water alkalinity,
  - the complete loss of alkalinity and buffering in more areas
  - and acidification of stagnant, ponded water bodies around the margins of the Lakes.

- It is recommended that limited biannual monitoring of AAS environments should be undertaken at potential acidification hot spots (e.g. Dog Lake, Boggy Lake, Campbell Park, Finniss River and the northern side of Lake Albert) to assess when and if a return to pre-drought conditions have been attained.

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APPENDIX A. SUPPORTING DATA

The following appendix provides additional supporting data on specific soil profiles that explains how their morphology and chemistry have changed through time and includes:

- Plots of soil characteristics from all layers sampled.
- Summaries of acidification potential, ASS material classification and acidification hazard.
- Summaries of temporal changes (including site photographs) that occurred at each site.

A.1 LF01: Wallys Landing and Wetland

LF01-A

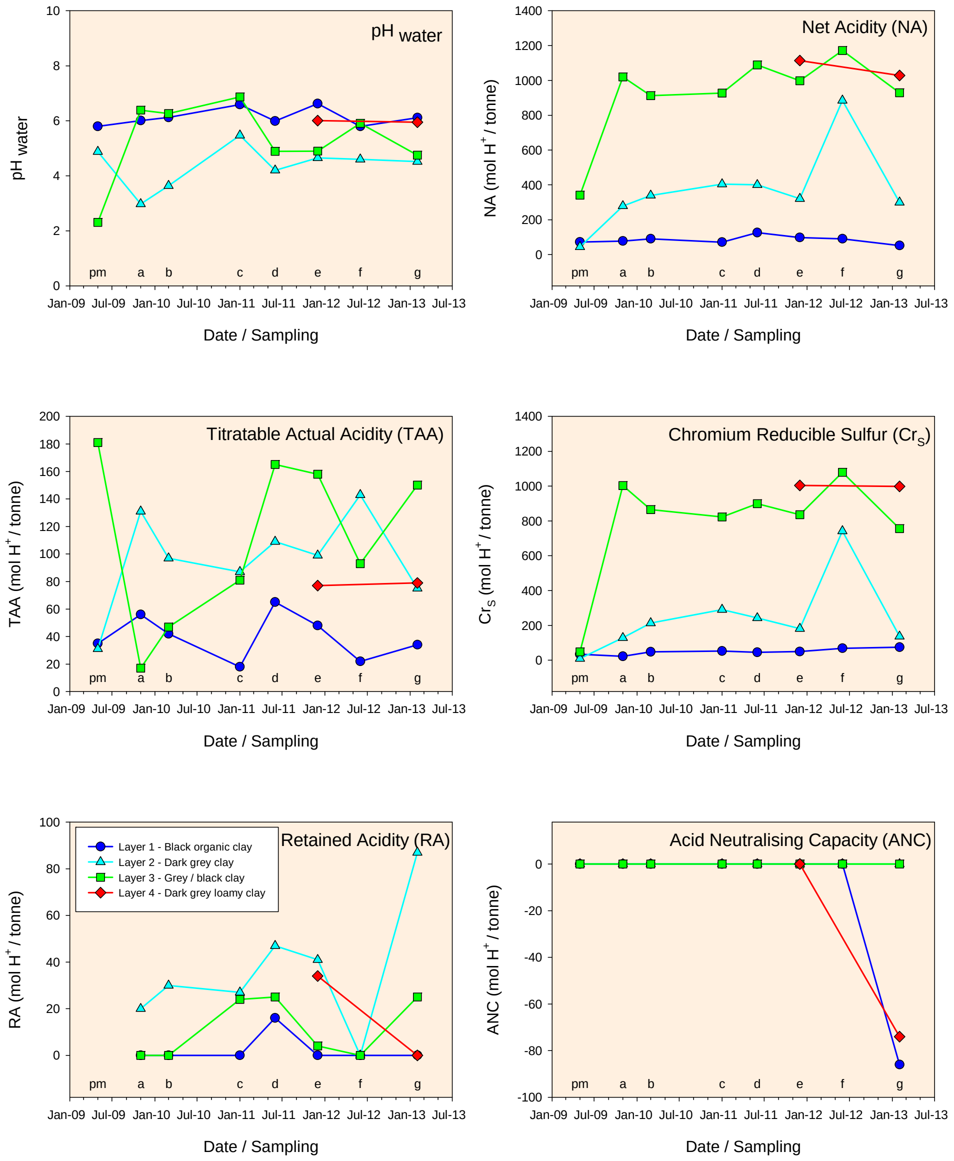


Figure A-1. Plots describing the location and quantity of acidity and acid neutralisation capacity within the soil profile and how this alters through time in response to drought and subsequent reflooding

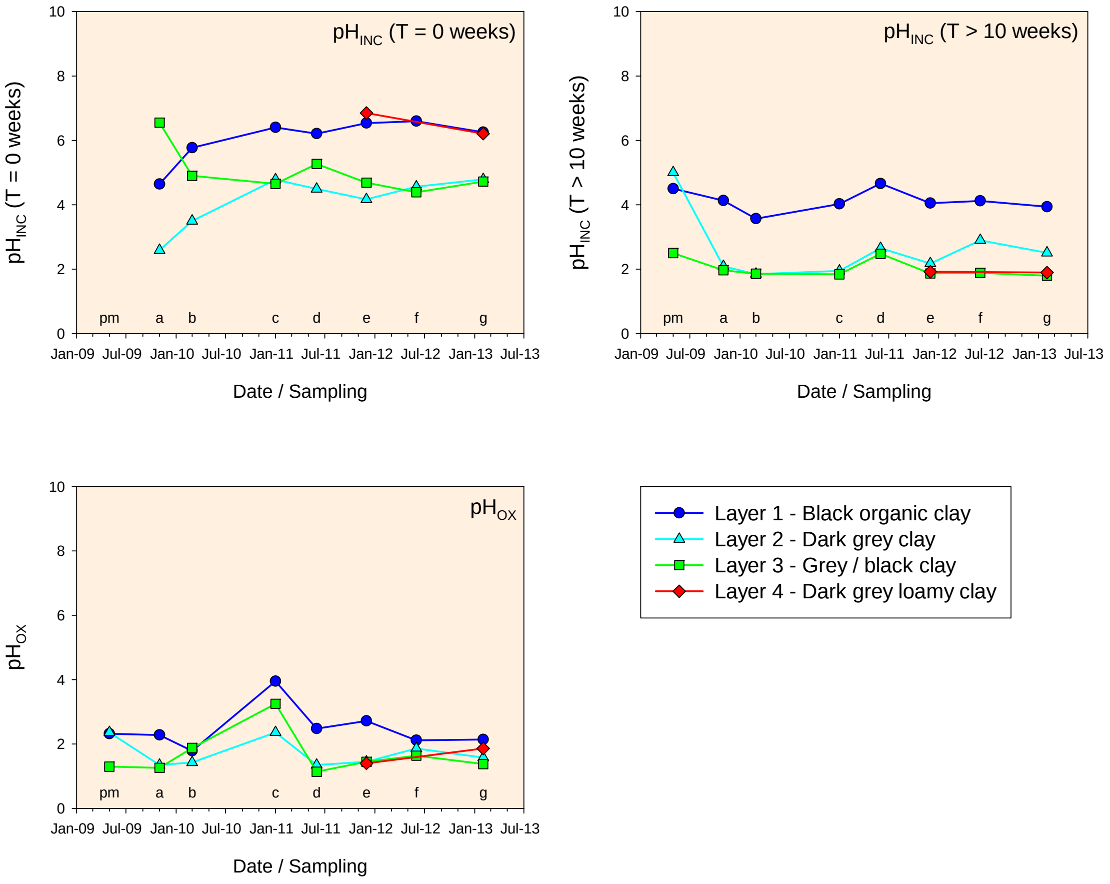


Figure A-2. Plots describing the acidification potential of soil material from different depths in the soil profile through time (will also add the time to reflooding as a vertical line)

Table A-1 Summary of acidification potential, ASS material classification, ASS subtype classification and acidification hazard (* indicates sulfuric soil material). The soil texture in brackets following the ASS subtype classification indicates the dominant texture of the profile. The layer number refers to soil layers and corresponding data that are plotted in the previous two figures. NC: non-continuous soil layers that were not encountered during the majority of samplings

Sample	Sampling	Layer	Depth (cm)	pH_{OX} < 2.5	pH_{INC} < 4.0	NA > 0	Acidification potential	ASS material classification	ASS subtype	Acidification hazard
LF01-A										
FIN 26M3 5.1	pm	1	0-5	1	0	1	2	Hyposulfidic clay	Sulfuric subaqueous clay soil (clay)	**High**
FIN 26M3 5.2		2	5-20	1	0	1	2	Hyposulfidic clay		
FIN 26M3 5.3		NC	20-25	1	1	1	**3***	Sulfuric sandy clay		
FIN 26M3 5.4		3	25-50	1	1	1	**3***	Sulfuric clay		
LFa01-A.1	a	1	0-10	1	0	1	2	Hyposulfidic clay	Sulfuric subaqueous clay soil (clay)	**High**
LFa01-A.2		2	10-40	1	1	1	**3***	Sulfuric clay		
LFa01-A.3		3	40-60	1	1	1	**3**	Hypersulfidic clay		
LFb01-A.1	b	1	0-10	1	1	1	**3**	Hypersulfidic clay	Sulfuric subaqueous clay soil (clay)	**High**
LFb01-A.2		2	10-40	1	1	1	**3***	Sulfuric clay		
LFb01-A.3		3	40-90	1	1	1	**3**	Hypersulfidic clay		
LFc01-A.1	c	1	0-10	0	0	1	1	Hyposulfidic clayey gel	Hypersulfidic subaqueous clay soil (clay)	**High**
LFc01-A.2		2	10-30	1	1	1	**3**	Hypersulfidic clay		
LFc01-A.3		3	30-90	0	1	1	2	Hypersulfidic clay		
LFd01-A.1	d	1	0-17	1	0	1	2	Hyposulfidic loamy clay	Hypersulfidic subaqueous clay soil (clay)	**High**
LFd01-A.2		2	17-55	1	1	1	**3**	Hypersulfidic clay		
LFd01-A.3		3	55-89	1	1	1	**3**	Hypersulfidic clay		
LFe01 A.1	e	1	0-11	0	0	1	1	Hyposulfidic hemic peat	Hypersulfidic subaqueous clay soil (clay)	**High**
LFe01-A.3		2	15-38	1	1	1	**3**	Hypersufilidic sand		
LFe01-A.4		3	38-59	1	1	1	**3**	Hypersufilidic heavy clay		
LFe01-A.5		4	59-86	1	1	1	**3**	Hypersufilidic loamy clay		
LFf01-A.1	f	1	0-14	1	0	1	2	Hyposulfidic hemic peat	Hypersulfidic subaqueous clay soil (clay)	**High**
LFf01-A.2		NC	14-16	1	1	1	**3**	Hypersufilidic sand		
LFf01-A.3		2	16-41	1	1	1	**3**	Hypersufilidic heavy clay		
LFf01-A.4		3	41-57	1	1	1	**3**	Hypersufilidic heavy clay		
LFg01-A.1	g	1	0-15	1	1	1	**3**	Hypersufilidic hemic peat	Hypersulfidic subaqueous clay soil (clay)	**High**
LFg01-A.2		NC	15-19	1	1	1	**3**	Hypersufilidic sand		
LFg01-A.3		2	19-35	1	1	1	**3**	Hypersufilidic sandy clay		
LFg01-A.4		3	35-51	1	1	1	**3**	Hypersufilidic sandy clay		
LFg01-A.5		4	51-86	1	1	1	**3**	Hypersufilidic heavy clay		

Table A-2. Summary of temporal changes in ASS Classification, acidification hazard [1](**H** = High; **M** = medium; **L** = Low; **VL** = Very Low), site condition and profile chemistry and morphology (Refer to previous two figures and table)

Sampling	**ASS Classification & [1]Acidification hazard**	**Site photographs**	**Notes**
Pre-monitoring Drought End Summer 2009 (pm)	**Sulfuric subaqueous clay (H)**		During the extreme drought (2007 to 2009) the partial drying of the wetland caused the Hypersulfidic subaqueous clays transform to Sulfuric clays. When the Sulfuric clays were rewetted after summer rainfall in 2009, acidic pools of water (pH <3.5) formed. Further inundation following winter 2009 neutralised the acidic pools and caused the formation of Sulfuric subaqueous clays. Prolonged inundation encouraged sulfate reduction and caused the formation of Hypersulfidic subaqueous clays.
Drought End winter 2009 (a)	**Sulfuric* subaqueous clay (H)**		
Drought End summer 2010 (b)	**Sulfuric* subaqueous clay (H)**		
Post-drought Summer 2011 (c)	**Hypersulfidic subaqueous clay (H)**		
Post-drought Winter 2011 (d)	**Hypersulfidic subaqueous clay (H)**		
Post-drought Start summer 2011/12 (e)	**Hypersulfidic subaqueous clay (H)**		
Post-drought Start winter 2012 (f)	**Hypersulfidic subaqueous clay (H)**		
Post-drought Summer 2013 (g)	**Hypersulfidic subaqueous clay (H)**		

A.2 LF02: Point Sturt North

LF02-A

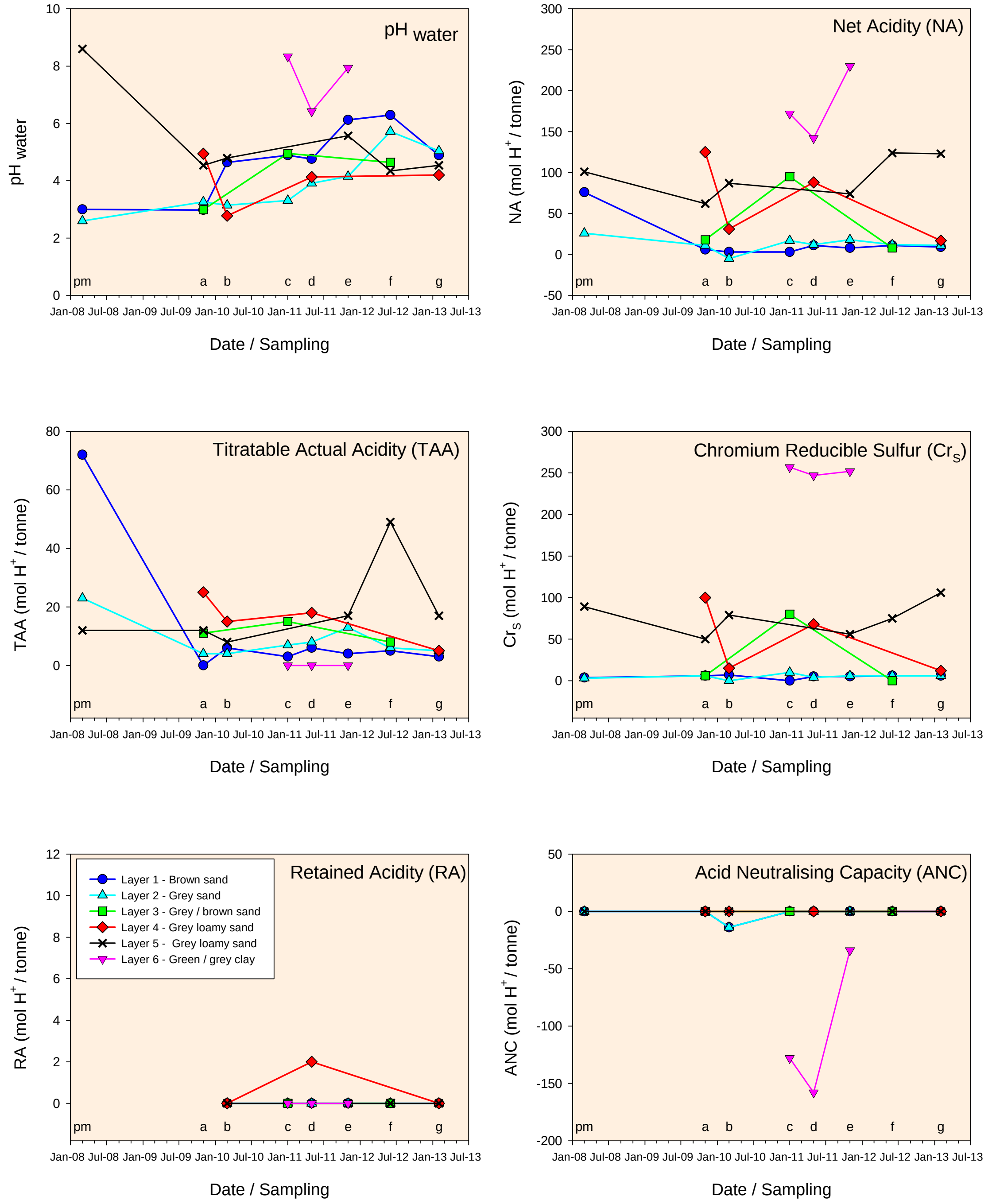


Figure A-3. Plots describing the location and quantity of acidity and acid neutralisation capacity within the soil profile and how this alters through time in response to drought and subsequent reflooding

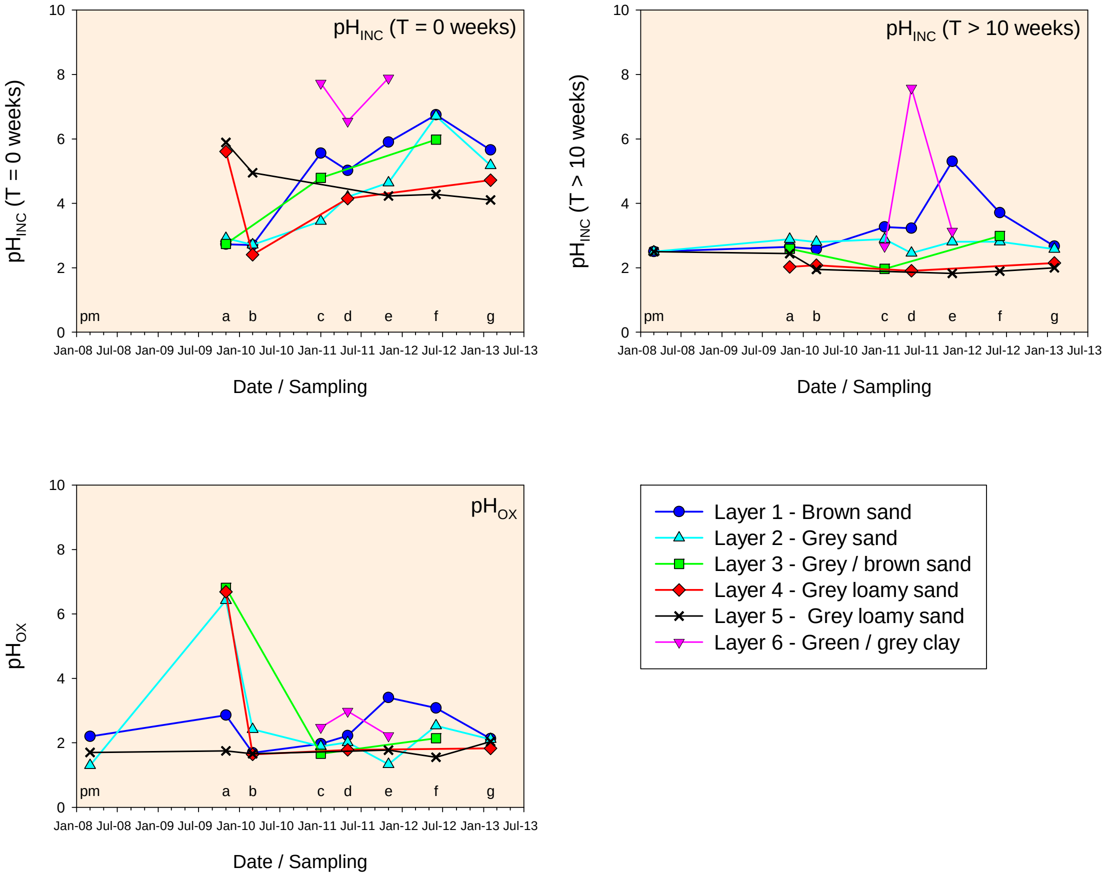
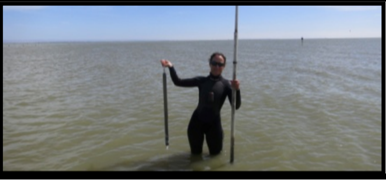


Figure A-4. Plots describing the acidification potential of soil material from different depths in the soil profile through time (will also add the time to reflooding as a vertical line)

Table A-3 Summary of acidification potential, ASS material classification, ASS subtype classification and acidification hazard (* indicates sulfuric soil material). The soil texture in brackets following the ASS subtype classification indicates the dominant texture of the profile. The layer number refers to soil layers and corresponding data that are plotted in the previous two figures. NC: non-continuous soil layers that were not encountered during the majority of samplings

Sample	**Sampling**	**Layer**	**Depth (cm)**	**pH_{OX} < 2.5**	**pH_{INC} < 4.0**	**NA > 0**	**Acidification potential**	**ASS material classification**	**ASS subtype**	**Acidification hazard**
LF02-A										
AA 29.5	pm	1	0-3	1	1	1	**3***	Sulfuric sand	Sulfuric soil (sand)	**High**
AA 29.6		NC	3-10	1	1	1	**3***	Sulfuric sand		
AA 29.7		2	10-15	1	1	1	**3***	Sulfuric sand		
AA 29.8		NC	15-35	1	1	1	**3***	Sulfuric sand		
AA 29.9		5	35-60	1	1	1	**3**	Hypersulfidic clay		
AA 29.10		NC	60-70	1	1	1	**3**	Hypersulfidic sand		
LFa02-A.1	a	1	0-8	0	1	1	2*	Sulfuric sand	Sulfuric soil (sand)	**High**
LFa02-A.2		2	8-25	0	1	1	2*	Sulfuric sand		
LFa02-A.3		3	25-40	0	1	1	2*	Sulfuric sand		
LFa02-A.4		4	40-70	0	1	1	2	Hypersulfidic loamy sand		
LFa02-A.5		5	70-77	1	1	1	**3**	Hypersulfidic loamy sand		
LFb02-A.1	b	1	0-4	1	1	1	**3**	Hypersulfidic sand	Sulfuric soil (sand)	**High**
LFb02-A.2		NC	4-12	1	1	1	**3***	Sulfuric sand		
LFb02-A.3		2	12-38	1	1	0	2*	Sulfuric sand		
LFb02-A.4		4	38-50	1	1	1	**3***	Sulfuric loamy sand		
LFb02-A.5		5	50-80	1	1	1	**3**	Hypersulfidic loamy sand		
LFc02-A.1	c	1	0-13	1	1	1	**3**	Sand	Sulfuric subaqueous soil (sand)	**High**
LFc02-A.2		2	13-25	1	1	1	**3***	Sulfuric sand		
LFc02-A.3		3	25-57	1	1	1	**3**	Hypersulfidic sand		
LFc02-A.4		6	57-60	1	1	1	**3**	Hypersulfidic clay		
LFd02-A.1	d	1	0-19	1	1	1	**3**	Sand	Sulfuric subaqueous soil (sand)	**High**
LFd02-A.2		2	19-33	1	1	1	**3***	Sulfuric sand		
LFd02-A.3		4	33-61	1	1	1	**3**	Hypersulfidic loamy sand		
LFd02-A.4		6	61-78	0	0	1	1	Hyposulfidic clay		
LFe02-A.1	e	1	0-4	0	0	1	1	Sand	Hypersulfidic subaqueous soil (sand)	**High**
LFe02-A.2		NC	4-13	1	1	1	**3**	Loamy sand		
LFe02-A.3		2	13-25	1	1	1	**3**	Sand		
LFe02-A.4		5	25-57	1	1	1	**3**	Hypersulfidic clayey sand		
LFe02-A.5		6	57-69	1	1	1	**3**	Hypersulfidic heavy clay		
LFf02-A.1	f	1	0-8	0	1	1	2	Hypersufilidic sand	Hypersulfidic subaqueous soil (sand)	**High**
LFf02-A.2		2	8-23	0	1	1	2	Hypersufilidic sand		
LFf02-A.3		3	23-42	1	1	1	**3**	Sand		
LFf02-A.4		5	42-67	1	1	1	**3**	Hypersulfidic sandy clay		
LFg02-A.1	g	1	0-22	1	1	1	**3**	Hypersufilidic silty sand	Hypersulfidic subaqueous soil (sand)	**High**
LFg02-A.2		2	22-37	1	1	1	**3**	Hypersufilidic silty sand		
LFg02-A.3		4	37-55	1	1	1	**3**	Hypersufilidic silty sand		
LFg02-A.4		5	55-78	1	1	1	**3**	Hypersufilidic silty sand		

Table A-4. Summary of temporal changes in ASS Classification, acidification hazard [1](**H** = High; **M** = medium; **L** = Low; **VL** = Very Low), site condition and profile chemistry and morphology (Refer to previous two figures and table)

Sampling	[1]ASS Classification & [2]Acidification hazard	Site photographs	Notes
Pre-monitoring Drought Summer 2008 (pm)	**Sulfuric (H)**		During the extreme drought period (2007 to 2009) the partial drying of the lake caused the formation of Sulfuric soils. Prolonged inundation, following winter 2010, caused the formation of Sulfuric subaqueous soil that developed into Hypersulfidic subaqueous soil.
Drought End winter 2009 (a)	**Sulfuric (H)**		
Drought End summer 2010 (b)	**Sulfuric* (H)**		
Post-drought Summer 2011 (c)	**Sulfuric subaqueous (H)**		
Post-drought Winter 2011 (d)	**Sulfuric subaqueous (H)**		
Post-drought Start summer 2011/12 (e)	**Hypersulfidic subaqueous (H)**		
Post-drought Start winter 2012 (f)	**Hypersulfidic subaqueous (H)**		
Post-drought Summer 2013 (g)	**Hypersulfidic subaqueous (H)**		

LF02-D

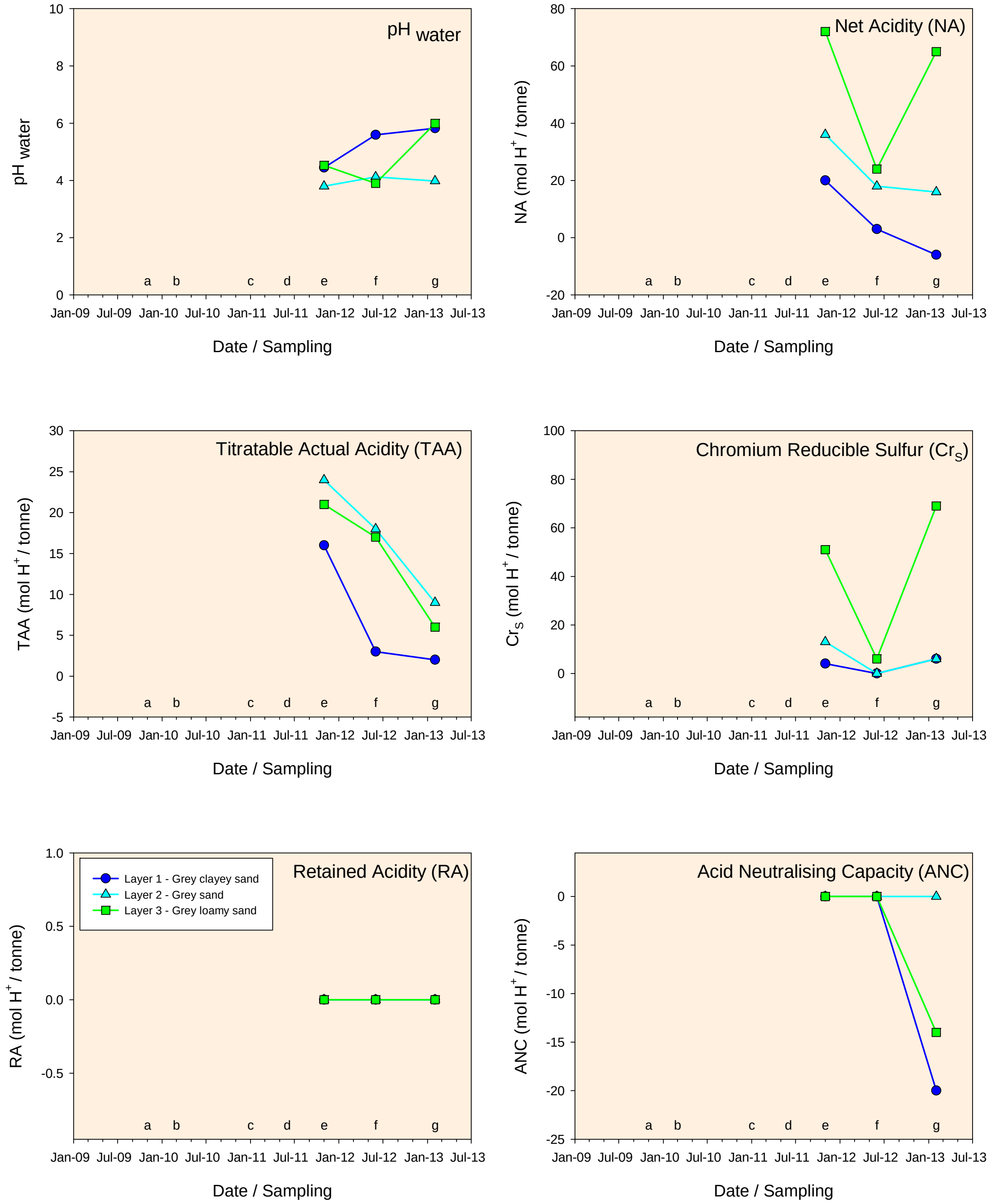


Figure A-5. Plots describing the location and quantity of acidity and acid neutralisation capacity within the soil profile and how this alters through time in response to drought and subsequent reflooding

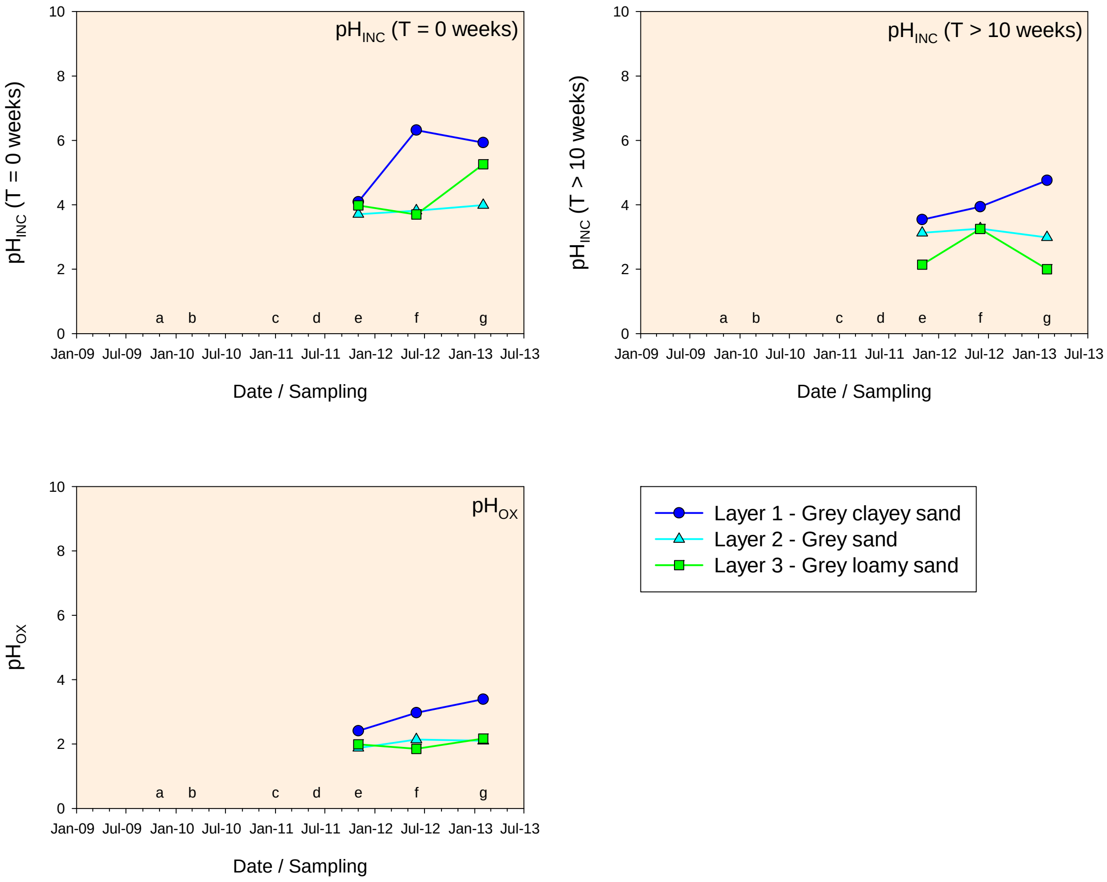
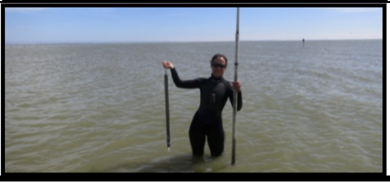


Figure A-6. Plots describing the acidification potential of soil material from different depths in the soil profile through time

Table A-5 Summary of acidification potential, ASS material classification, ASS subtype classification and acidification hazard (* indicates sulfuric soil material). The soil texture in brackets following the ASS subtype classification indicates the dominant texture of the profile. The layer number refers to soil layers and corresponding data that are plotted in the previous two figures. NC: non-continuous soil layers that were not encountered during the majority of samplings

Sample	**Sampling**	**Layer**	**Depth (cm)**	**$\mathrm{pH_{OX}}$ < 2.5**	**$\mathrm{pH_{INC}}$ < 4.0**	**NA > 0**	**Acidification potential**	**ASS material classification**	**ASS subtype**	**Acidification hazard**
LF02-D										
LFe02-D.1	e	1	0-7	0	0	1	1	Hyposulfidic sand	Sulfuric subaqueous soil (sand)	**High**
LFe02-D.2		2	7-19	1	1	1	**3**	Clayey sand		
LFe02-D.3		3	19-31	1	1	1	**3***	Sulfuric clayey sand		
LFe02-D.4		4	31-47	1	1	1	**3**	Hypersulfidic clayey sand		
LFe02-D.5		5	47-56	0	0	0	0	Hyposulfidic heavy clay		
LFf02-D.1	f	2	0-11	0	1	1	2	Loamy sand	Sulfuric subaqueous soil (sand)	**High**
LFf02-D.2		3	11-25	1	1	1	**3**	Loamy sand		
LFf02-D.3		4	25-40	1	1	1	**3***	Sulfuric loamy sand		
LFf02-D.4		NC	40-72	1	1	1	**3**	Hypersulfidic sandy loam		
LFg02-D.1	g	2	0-10	0	0	0	0	Hyposulfidic silty sand	Sulfuric subaqueous soil (sand)	**High**
LFg02-D.2		3	10-45	1	1	1	**3***	Sulfuric silty sand		
LFg02-D.3		4	45-75	1	1	1	**3**	Hypersulfidic clayey sand		

Table A-6. Summary of temporal changes in ASS Classification, acidification hazard [1](**H** = High; **M** = medium; **L** = Low; **VL** = Very Low), site condition and profile chemistry and morphology (Refer to previous two figures and table)

Sampling	[1]**ASS Classification & [2]Acidification hazard**	**Site photographs**	**Notes**
Post-drought Start summer 2011/12 (e)	**Sulfuric subaqueous (H)**		Following inundation in winter 2010, soil material remained Sulfuric subaqueous clay soil.
Post-drought Start winter 2012 (f)	**Sulfuric subaqueous (H)**		
Post-drought Summer 2013 (g)	**Sulfuric subaqueous (H)**		

A.3 LF03: Milang

LF03-A

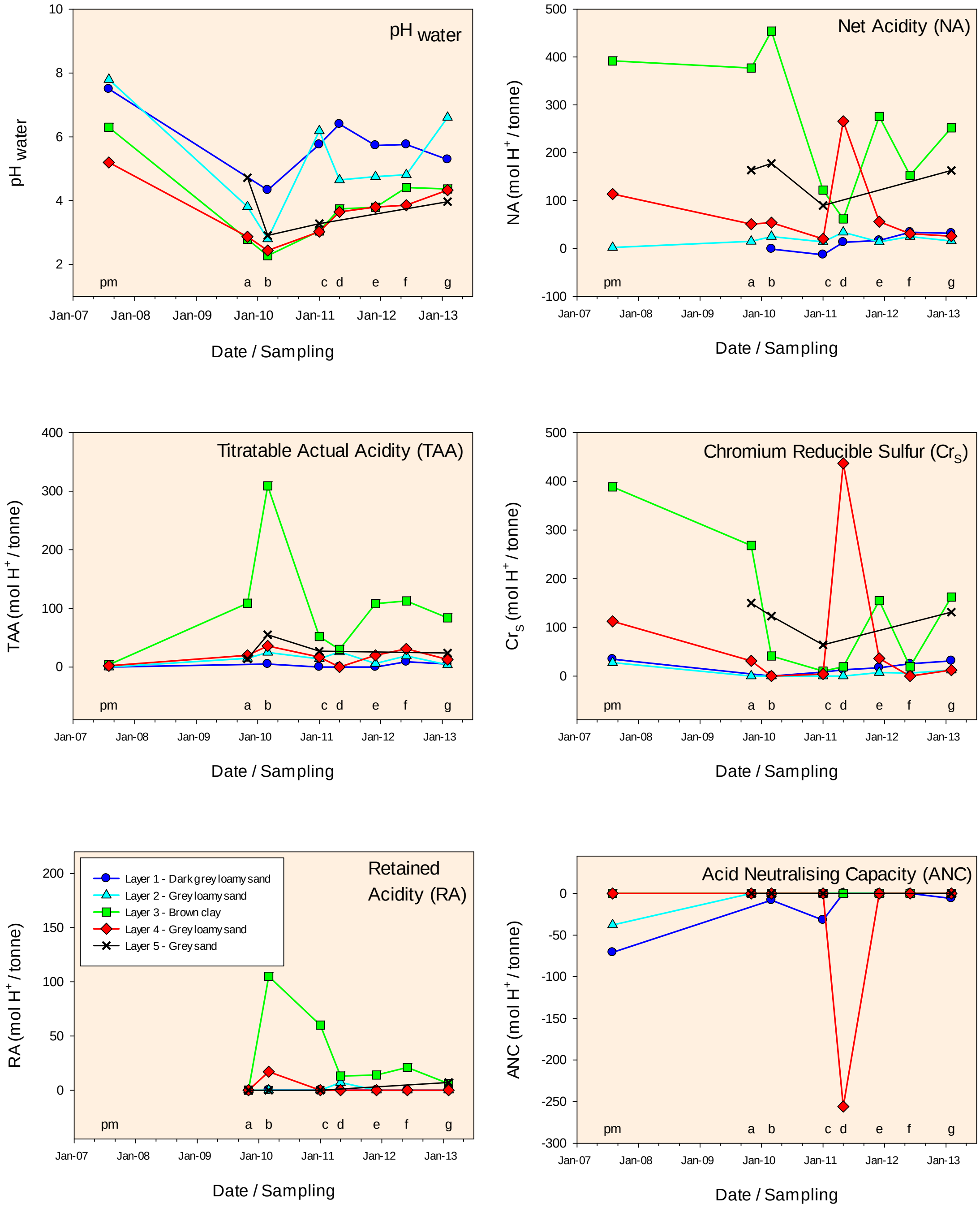


Figure A-7. Plots describing the location and quantity of acidity and acid neutralisation capacity within the soil profile and how this alters through time in response to drought and subsequent reflooding

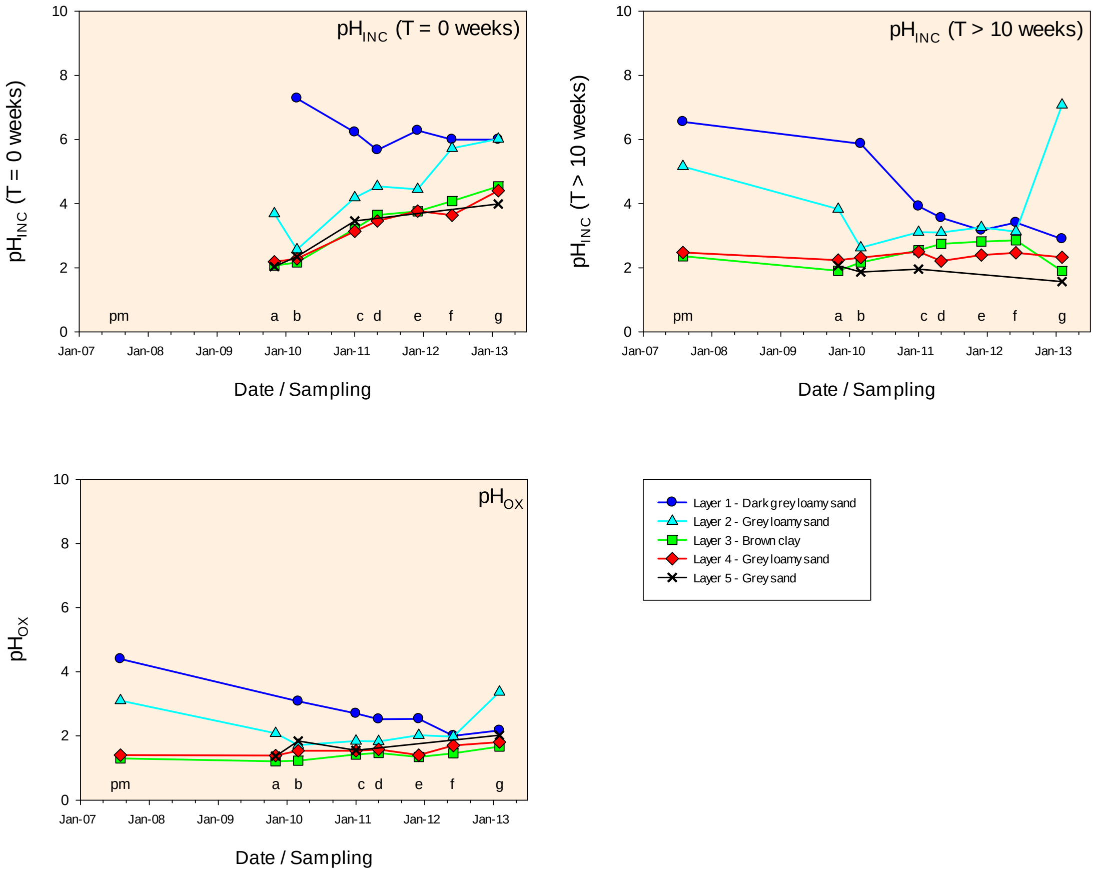
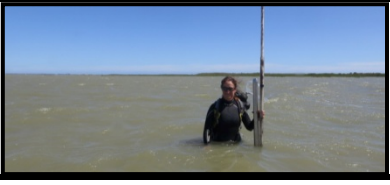


Figure A-8. Plots describing the acidification potential of soil material from different depths in the soil profile through time

Table A-7 Summary of acidification potential, ASS material classification, ASS subtype classification and acidification hazard (* indicates sulfuric soil material). The soil texture in brackets following the ASS subtype classification indicates the dominant texture of the profile. The layer number refers to soil layers and corresponding data that are plotted in the previous two figures. NC: non-continuous soil layers that were not encountered during the majority of samplings

Sample	Sampling	Layer	Depth (cm)	pH_{OX} < 2.5	pH_{INC} < 4.0	NA > 0	Acidification potential	ASS material classification	ASS subtype	Acidification hazard
LF03-A										
AA 16.1	pm	1	0-3	0	0	0	0	Hyposulfidic sand	Hypersulfidic subaqueous clay soil (sand)	**High**
AA 16.2		2	3-12	0	0	0	0	Hyposulfidic silt		
AA 16.3		NC	12-20	1	0	1	2	Hyposulfidic silty sand		
AA 16.4		3	20-30	1	1	1	3	Hypersulfidic clay		
AA 16.5		4	30-50	1	1	1	3	Hypersulfidic clay		
AA 16.6		NC	50-80	1	1	1	3	Hypersulfidic sand		
LFa03-A.1	a	2	0-30	1	1	1	3*	Sulfuric fine sand	Sulfuric soil (sand)	**High**
LFa03-A.2		3	30-40	1	1	1	3*	Sulfuric clay		
LFa03-A.3		4	40-50	1	1	1	3*	Sulfuric coarse sand		
LFa03-A.4		5	50-70	1	1	1	3	Hypersulfidic sand		
LFb03-A.1	b	1	0-5	0	0	0	0	Hyposulfidic loamy sand	Sulfuric clay soil (sand)	**High**
LFb03-A.2		2	5-25	1	1	1	3*	Sulfuric loamy sand		
LFb03-A.3		3	25-40	1	1	1	3*	Sulfuric heavy clay		
LFb03-A.4		4	40-62	1	1	1	3*	Sulfuric loamy sand		
LFb03-A.5		5	62-100	1	1	1	3*	Sulfuric sand		
LFb03-A.6		6	100-110	1	1	1	3	Hypersulfidic heavy clay		
LFc03-A.1	c	1	0-7	0	1	0	1	Hypersulfidic loamy sand	Sulfuric subaqueous clay soil (sand)	**High**
LFc03-A.2		2	7-16	1	1	1	3	loamy sand		
LFc03-A.3		3	16-24	1	1	1	3*	Sulfuric clay		
LFc03-A.4		4	24-54	1	1	1	3*	Sulfuric loamy sand		
LFc03-A.5		5	54-63	1	1	1	3*	Sulfuric sand		
LFd03-A.1	d	1	0-10	0	1	1	2	Hypersulfidic loamy sand	Sulfuric subaqueous soil (sand)	**High**
LFd03-A.2		2	10-16	1	1	1	3	Loamy sand		
LFd03-A.3		3	16-21	1	1	1	3*	Sulfuric clay		
LFd03-A.4		4	21-47	1	1	1	3*	Sulfuric loamy sand		
LFe03-A.1	e	1	0-10	0	1	1	2	Hypersufilidic loamy sand	Sulfuric subaqueous soil (sand)	**High**
LFe03-A.2		2	10-16	1	1	1	3	Hypersufilidic loamy sand		
LFe03-A.3		3	16-19	1	1	1	3*	Sulfuric heavy clay		
LFe03-A.4		4	19-42	1	1	1	3*	Sulfuric loamy sand		
LFe03-A.5		NC	42-48	1	1	1	3	Hypersufilidic sapric peat		
LFf03-A.1	f	1	0-15	1	1	1	3	Hypersufilidic loamy fine sand	Sulfuric subaqueous soil (sand)	**High**
LFf03-A.2		2	15-20	1	1	1	3	Hypersufilidic loamy fine sand		
LFf03-A.3		3	20-26	1	1	1	3	Hypersufilidic heavy clay		
LFf03-A.4		4	26-60	1	1	1	3*	Sulfuric loamy sand		
LFg03-A.1	g	1	0-10	1	1	1	3	Hypersufilidic loamy sand	Sulfuric subaqueous soil (sand)	**High**
LFg03-A.2		2	10-22	0	0	1	1	Hyposulfidic sand		
LFg03-A.3		3	22-28	1	1	1	3	Hypersufilidic heavy clay		
LFg03-A.4		4	28-42	1	1	1	3	Hypersufilidic loamy sand		
LFg03-A.5		5	42-57	1	1	1	3*	Sulfuric loamy sand		

Table A-8. Summary of temporal changes in ASS Classification, acidification hazard [1](**H** = High; **M** = medium; **L** = Low; **VL** = Very Low), site condition and profile chemistry and morphology (Refer to previous two figures and table)

Sampling	[1]ASS Classification & [2]Acidification hazard	Site photographs	Notes
Pre-monitoring Pre-drought Winter 2007 (pm)	**Hypersulfidic subaqueous clay (H)**		During the extreme drought period (2007 to 2009) the partial drying of the lake caused Hypersulfidic subaqueous clay soil to transform to Sulfuric clay soil. Inundation, following winter 2010, caused the formation of Sulfuric subaqueous (clay) soil.
Drought End winter 2009 (a)	**Sulfuric (H)**		
Drought End summer 2010 (b)	**Sulfuric* clay (H)**		
Post-drought Summer 2011 (c)	**Sulfuric subaqueous clay (H)**		
Post-drought Winter 2011 (d)	**Sulfuric subaqueous (H)**		
Post-drought Start summer 2011/12 (e)	**Sulfuric subaqueous (H)**		
Post-drought Start winter 2012 (f)	**Sulfuric subaqueous (H)**		
Post-drought Summer 2013 (g)	**Sulfuric subaqueous (H)**		

A.4 LF04: Toldérol

LF04-A

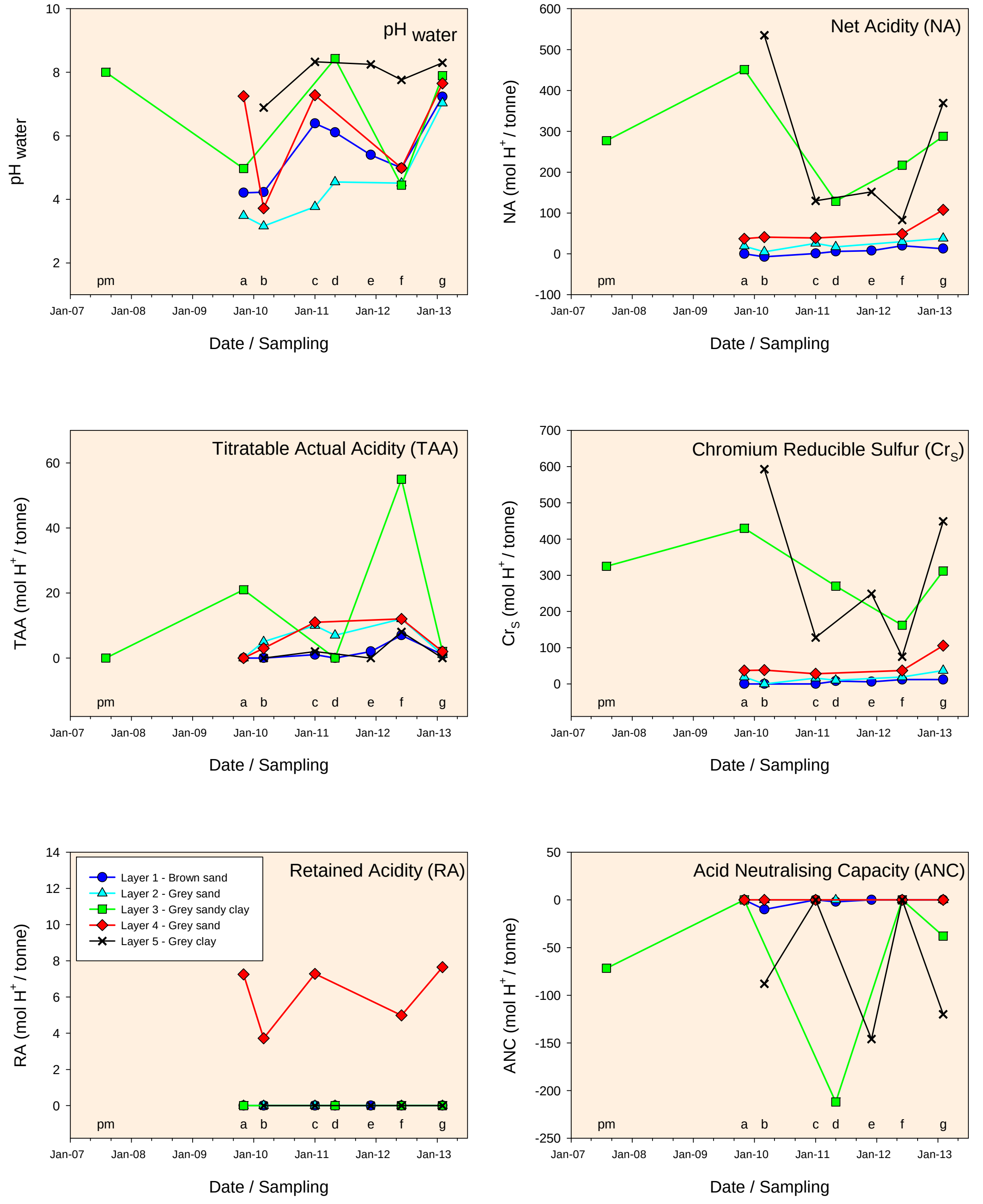


Figure A-9. Plots describing the location and quantity of acidity and acid neutralisation capacity within the soil profile and how this alters through time in response to drought and subsequent reflooding

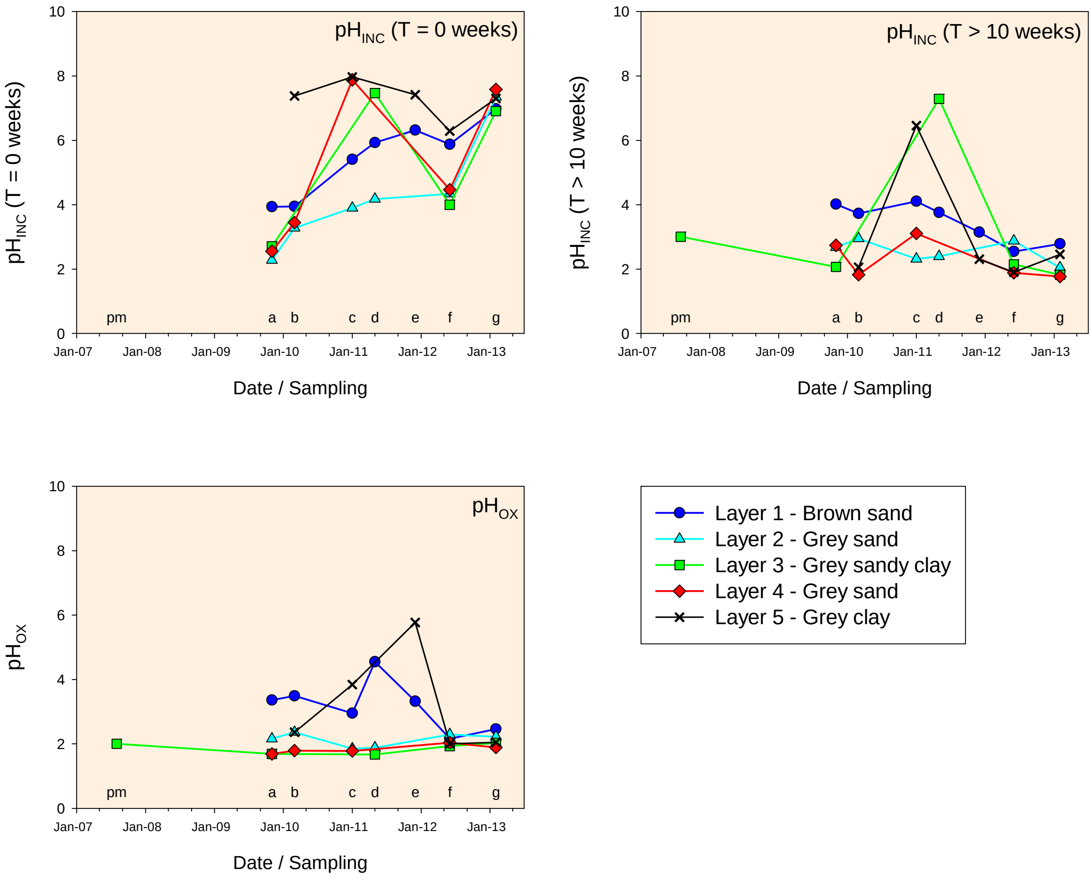
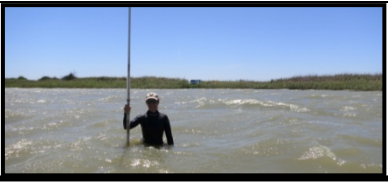


Figure A-10. Plots describing the acidification potential of soil material from different depths in the soil profile through time

Table A-9 Summary of acidification potential, ASS material classification, ASS subtype classification and acidification hazard (* indicates sulfuric soil material). The soil texture in brackets following the ASS subtype classification indicates the dominant texture of the profile. The layer number refers to soil layers and corresponding data that are plotted in the previous two figures. NC: non-continuous soil layers that were not encountered during the majority of samplings

Sample	**Sampling**	**Layer**	**Depth (cm)**	**pH_{OX} < 2.5**	**pH_{INC} < 4.0**	**NA > 0**	**Acidification potential**	**ASS material classification**	**ASS subtype**	**Acidification hazard**
LF04-A										
AA 13.2	pm	3	3-15	1	1	1	**3**	Hypersulfidic sandy clay	Hypersulfidic subaqueous clay soil (clay)	**High**
LFa04-A.1	a	1	0-25	0	0	0	0	Hyposulfidic sand	Sulfuric soil (sand)	**High**
LFa04-A.2		2	25-35	1	1	1	**3***	Sulfuric sand		
LFa04-A.3		3	35-42	1	1	1	**3**	Hypersulfidic sandy clay		
LFa04-A.4		4	42-55	1	1	1	**3**	Hypersulfidic sand		
LFb04-A.1	b	1	0-15	0	1	0	1	Hyposulfidic sand	Sulfuric soil (sand)	**High**
LFb04-A.2		2	15-26	1	1	1	**3***	Sulfuric sand		
LFb04-A.3		NC	26-40	1	1	1	**3***	Sulfuric sand		
LFb04-A.4		4	40-58	1	1	1	**3***	Sulfuric sand		
LFb04-A.5		5	58-65	1	1	1	**3**	Hypersulfidic heavy clay		
LFc04-A.1	c	1	0-18	0	0	1	1	Sand	Sulfuric subaqueous soil (sand)	**High**
LFc04-A.2		2	18-28	1	1	1	**3***	Sulfuric sand		
LFc04-A.3		NC	28-45	1	1	1	**3**	Hypersulfidic sand		
LFc04-A.4		4	45-58	1	1	1	**3**	Hypersulfidic sand		
LFc04-A.5		5	58-65	0	0	1	1	Hyposulfidic clay		
LFd04-A.1	d	1	0-10	0	1	1	2	Hypersulfidic sand	Hypersulfidic subaqueous soil (sand)	**High**
LFd04-A.2		2	10-20	1	1	1	**3**	Hypersulfidic sand		
LFd04-A.3		NC	20-38	1	1	1	**3**	Hypersulfidic sand		
LFd04-A.4		3	38-77	1	0	1	2	Hyposulfidic sand		
LFe04-A.1	e	1	0-5	0	1	1	2	Hypersufilidic sand	Hypersulfidic subaqueous soil (sand)	**High**
LFe04-A.2		NC	5-12	1	1	1	**3**	Hypersufilidic sand		
LFe04-A.3		NC	12-45	1	1	1	**3**	Hypersufilidic sand		
LFe04-A.4		5	45-67	0	1	1	2	Hypersufilidic heavy clay		
LFf04-A.1	f	1	0-10	1	1	1	**3**	Hypersufilidic sand	Hypersulfidic subaqueous soil (sand)	**High**
LFf04-A.2		2	10-23	1	1	1	**3**	Hypersufilidic sand		
LFf04-A.3		3	23-30	1	1	1	**3**	Hypersufilidic sandy clay		
LFf04-A.4		4	30-52	1	1	1	**3**	Hypersufilidic sand		
LFf04-A.5		5	52-80	1	1	1	**3**	Hypersufilidic sandy clay		
LFg04-A.1	g	1	0-15	1	1	1	**3**	Hypersufilidic sand	Hypersulfidic subaqueous soil (sand)	**High**
LFg04-A.2		2	15-45	1	1	1	**3**	Hypersufilidic sand		
LFg04-A.3		3	45-51	1	1	1	**3**	Hypersufilidic sandy clay		
LFg04-A.4		4	51-59	1	1	1	**3**	Hypersufilidic sand		
LFg04-A.5		5	59-69	1	1	1	**3**	Hypersufilidic sandy clay		

Table A-10. Summary of temporal changes in ASS Classification, acidification hazard [1](**H** = High; **M** = medium; **L** = Low; **VL** = Very Low), site condition and profile chemistry and morphology (Refer to previous two figures and table)

Sampling	[1]ASS Classification & [2]Acidification hazard	Site photographs	Notes
Pre-monitoring **Pre-drought** **Winter** **2007 (pm)**	**Hypersulfidic subaqueous clay (H)**		During the extreme drought period (2007 to 2009) the partial drying of the lake caused Hypersulfidic subaqueous clay soil to transform to Sulfuric soil. Inundation, following winter 2010, caused the formation of Sulfuric subaqueous soil. Prolonged inundation encouraged sulfate reduction and caused the formation of Hypersulfidic subaqueous clays.
Drought **End winter** **2009 (a)**	**Sulfuric (H)**		
Drought **End summer** **2010 (b)**	**Sulfuric (H)**		
Post-drought **Summer** **2011 (c)**	**Sulfuric subaqueous (H)**		
Post-drought **Winter** **2011 (d)**	**Hypersulfidic subaqueous (H)**		
Post-drought **Start summer** **2011/12 (e)**	**Hypersulfidic subaqueous (H)**		
Post-drought **Start winter** **2012 (f)**	**Hypersulfidic subaqueous (H)**		
Post-drought **Summer** **2013 (g)**	**Hypersulfidic subaqueous (H)**		

A.5 LF06: Poltalloch

LF06-A

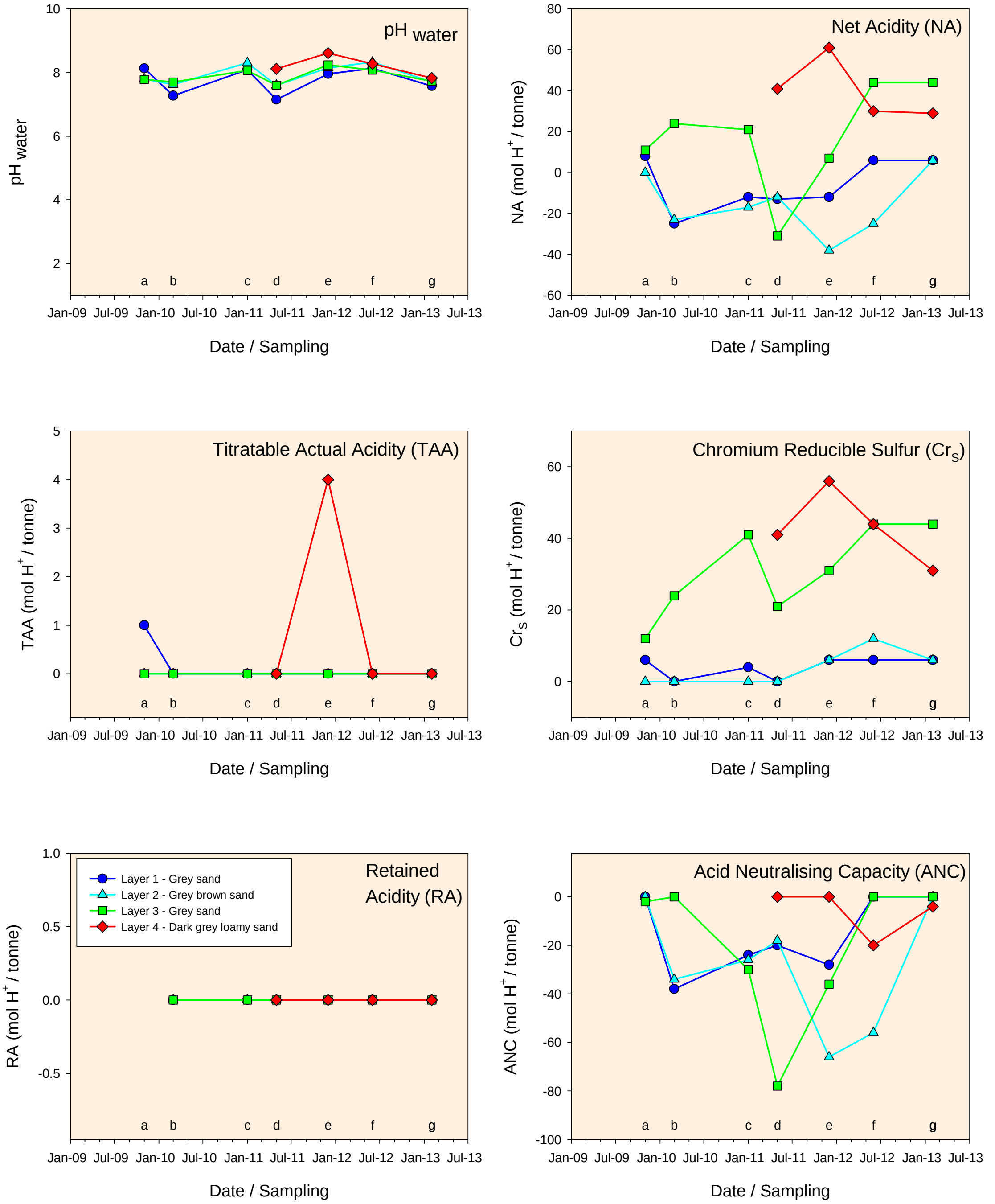


Figure A-11. Plots describing the location and quantity of acidity and acid neutralisation capacity within the soil profile and how this alters through time in response to drought and subsequent reflooding

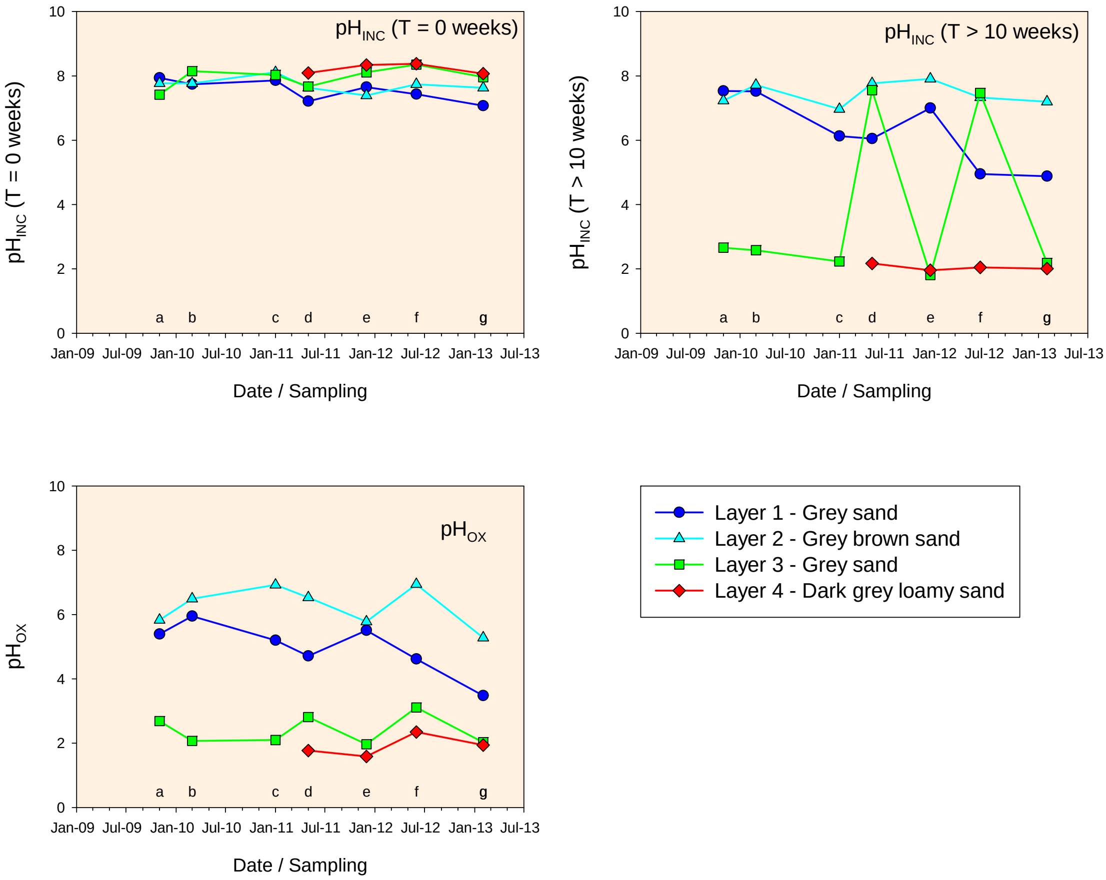


Figure A-12. Plots describing the acidification potential of soil material from different depths in the soil profile through time

Table A-11 Summary of acidification potential, ASS material classification, ASS subtype classification and acidification hazard (* indicates sulfuric soil material). The soil texture in brackets following the ASS subtype classification indicates the dominant texture of the profile. The layer number refers to soil layers and corresponding data that are plotted in the previous two figures. NC: non-continuous soil layers that were not encountered during the majority of samplings

Sample	Sampling	Layer	Depth (cm)	pH_{OX} < 2.5	pH_{INC} < 4.0	NA > 0	Acidification potential	ASS material classification	ASS subtype	Acidification hazard
LF06-A										
LFa06-A.1	a	1	0-20	0	0	1	1	Hyposulfidic sand	Hypersulfidic soil (sand)	**Low**
LFa06-A.2		2	20-45	0	0	0	0	Hyposulfidic sand		
LFa06-A.3		3	45-80	0	1	1	2	Hypersulfidic sand		
LFb06-A.1	b	1	0-28	0	0	0	0	Hyposulfidic sand	Hypersulfidic soil (sand)	**Low**
LFb06-A.2		2	28-55	0	0	0	0	Hyposulfidic sand		
LFb06-A.3		3	45-80	1	1	1	**3**	Hypersulfidic sand		
LFc06-A.1	c	1	0-18	0	0	0	0	sand	Hypersulfidic subaqueous soil (sand)	**Low**
LFc06-A.2		2	18-35	0	0	0	0	sand		
LFc06-A.3		3	35-49	1	1	1	**3**	Hypersulfidic sand		
LFc06-A.4		NC	49-61	0	1	1	2	Hypersulfidic sand		
LFd06-A.1	d	1	0-18	0	0	0	0	Sand	Hypersulfidic subaqueous soil (sand)	**Low**
LFd06-A.2		2	18-35	0	0	0	0	Sand		
LFd06-A.3		3	35-48	0	0	0	0	Hyposulfidic sand		
LFd06-A.4		NC	48-59	1	1	1	**3**	Hypersulfidic sand		
LFd06-A.5		4	59-83	1	1	1	**3**	Hypersulfidic loamy sand		
LFe06-A.1	e	1	0-9	0	0	0	0	Hyposulfidic sand	Hypersulfidic subaqueous soil (sand)	**Medium**
LFe06-A.2		2	9-22	0	0	0	0	Hyposulfidic sand		
LFe06-A.3		3	22-35	1	1	1	**3**	Hypersufilidic sand		
LFe06-A.4		NC	35-55	1	1	1	**3**	Hypersufilidic sand		
LFe06-A.5		4	55-66	1	1	1	**3**	Hypersufilidic loamy sand		
LFf06-A.1	f	1	0-29	0	0	1	1	Hyposulfidic loamy sand	Hypersulfidic subaqueous soil (sand)	**Low**
LFf06-A.2		2	29-45	0	0	0	0	Hyposulfidic sand		
LFf06-A.3		3	45-65	0	0	1	1	Hyposulfidic sand		
LFf06-A.4		4	65-83	1	1	1	**3**	Hypersufilidic loamy sand		
LFg06-A.1	g	1	0-22	0	0	1	1	Hyposulfidic sand	Hypersulfidic subaqueous soil (sand)	**Low**
LFg06-A.2		2	22-44	0	0	1	1	Hyposulfidic sand		
LFg06-A.3		3	44-64	1	1	1	**3**	Hypersufilidic sand		
LFg06-A.4		4	64-84	1	1	1	**3**	Hypersufilidic sand		

Table A-12. Summary of temporal changes in ASS Classification, acidification hazard [1](**H** = High; **M** = medium; **L** = Low; **VL** = Very Low), site condition and profile chemistry and morphology (Refer to previous two figures and table)

Sampling	[1]ASS Classification & [2]Acidification hazard	Site photographs	Notes
Drought End winter 2009 (a)	**Hypersulfidic (L)**		During the extreme drought period (2007 to 2009) and partial drying of the lake soil material generally remained Hypersulfidic. Inundation, following winter 2010, caused the formation of Hypersulfidic subaqueous soil.
Drought End summer 2010 (b)	**Hypersulfidic (L)**		
Post-drought Summer 2011 (c)	**Hypersulfidic subaqueous (L)**		
Post-drought Winter 2011 (d)	**Hypersulfidic subaqueous (L)**		
Post-drought Start summer 2011/12 (e)	**Hypersulfidic subaqueous (M)**		
Post-drought Start winter 2012 (f)	**Hypersulfidic subaqueous (L)**		
Post-drought Summer 2013 (g)	**Hypersulfidic subaqueous (L)**		

A.6 LF07: Waltowa

LF07-A

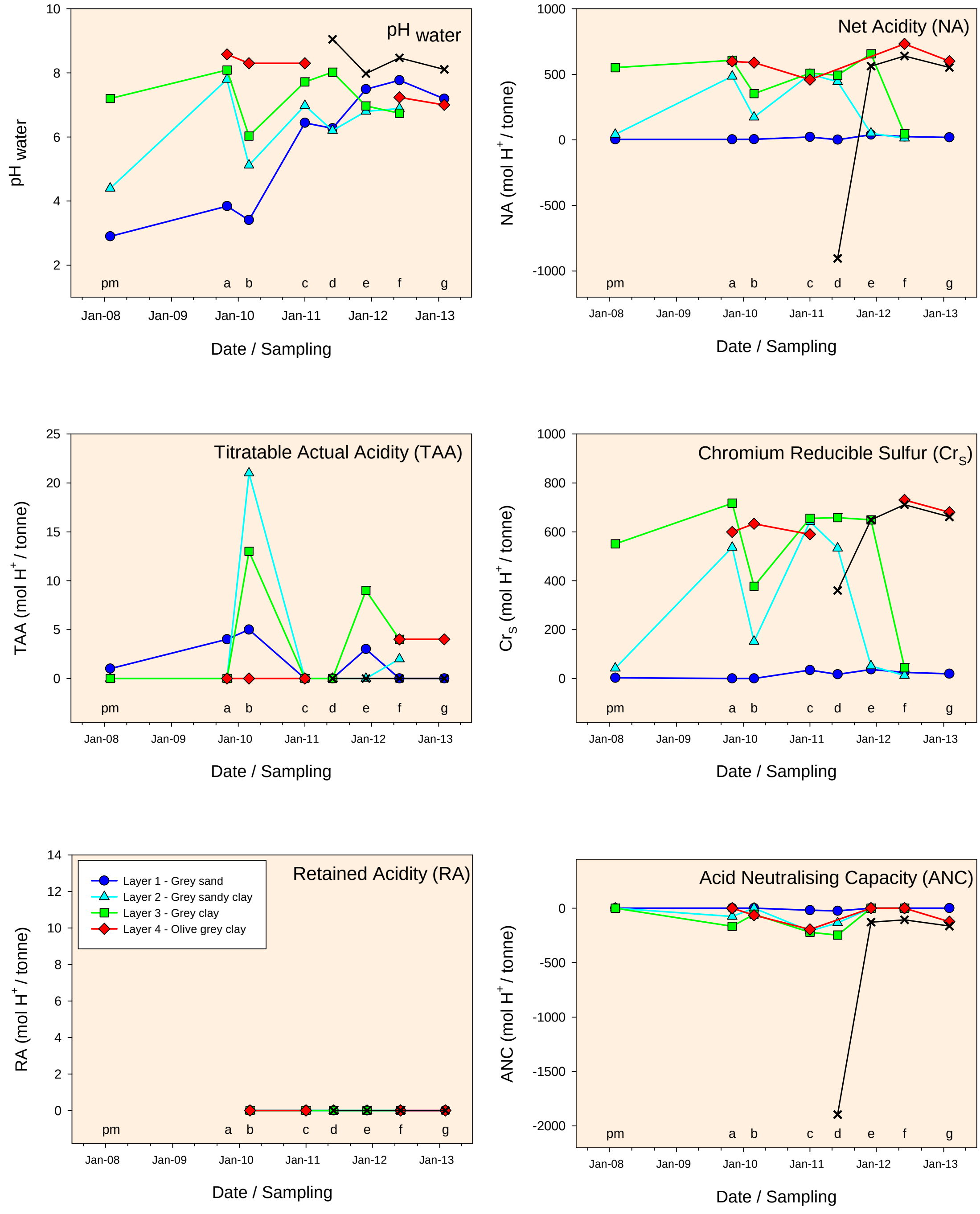


Figure A-13. Plots describing the location and quantity of acidity and acid neutralisation capacity within the soil profile and how this alters through time in response to drought and subsequent reflooding

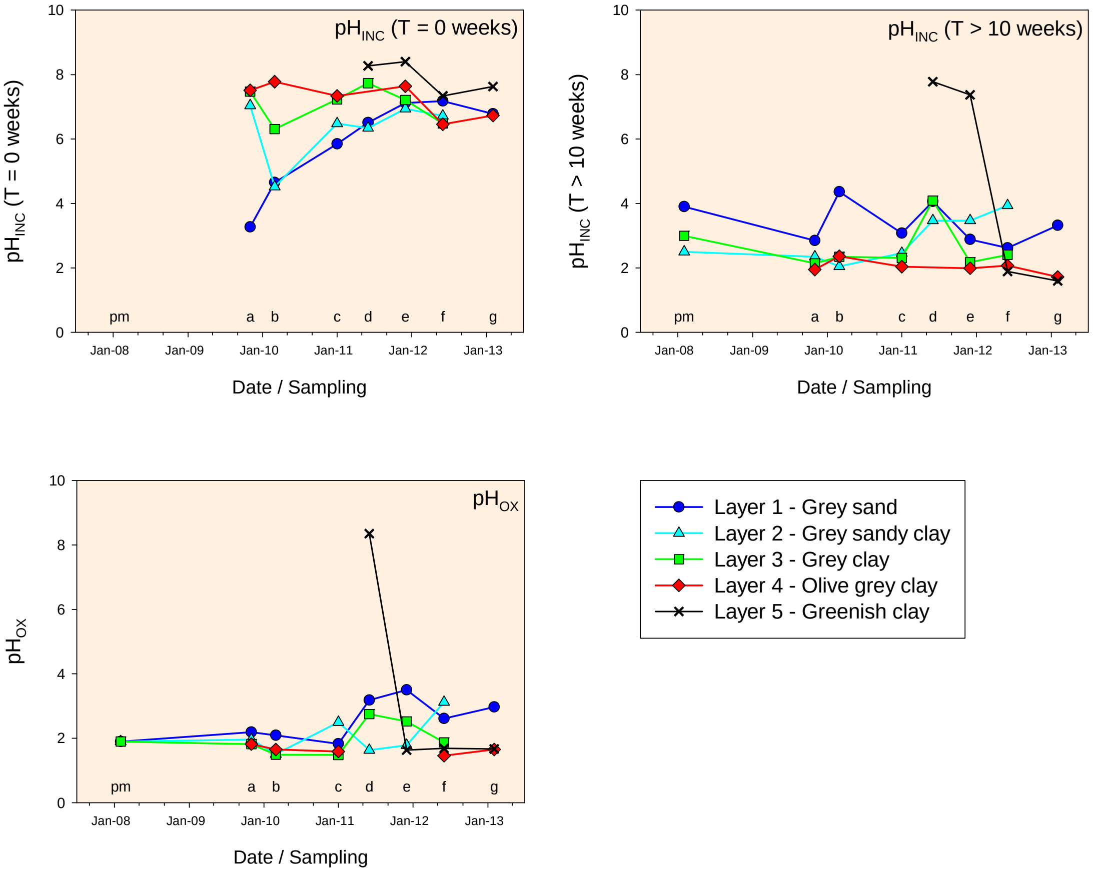


Figure A-14. Plots describing the acidification potential of soil material from different depths in the soil profile through time

Table A-13 Summary of acidification potential, ASS material classification, ASS subtype classification and acidification hazard (* indicates sulfuric soil material). The soil texture in brackets following the ASS subtype classification indicates the dominant texture of the profile. The layer number refers to soil layers and corresponding data that are plotted in the previous two figures. NC: non-continuous soil layers that were not encountered during the majority of samplings

Sample	**Sampling**	**Layer**	**Depth (cm)**	**pH_{OX} < 2.5**	**pH_{INC} < 4.0**	**NA > 0**	**Acidification potential**	**ASS material classification**	**ASS subtype**	**Acidification hazard**
LF07-A										
AT 12.1	pm	NC	0-5	0	0	0	0	Sand	Sulfuric soil (sand)	**High**
AT 12.2		1	5-25	1	0	0	2*	Sulfuric sand		
AT 12.3		2	25-40	1	1	1	**3**	Hypersulfidic loamy sand		
AT 12.4		3	40-70	1	1	1	**3**	Hypersulfidic sand		
LFa07-A.2	a	1	2-35	1	1	1	**3***	Sulfuric sand	Sulfuric clay soil (clay)	**High**
LFa07-A.3		2	35-50	1	1	1	**3**	Hypersulfidic sandy clay loam		
LFa07-A.4		3	50-70	1	1	1	**3**	Hypersulfidic medium clay		
LFa07-A.5		4	70-80	1	1	1	**3**	Hypersulfidic medium clay		
LFb07-A.2	b	1	2-35	1	0	1	2*	Sulfuric sand	Sulfuric clay soil (clay)	**High**
LFb07-A.3		2	35-50	1	1	1	**3**	Hypersulfidic sandy clay loam		
LFb07-A.4		3	50-70	1	1	1	**3**	Hypersulfidic medium clay		
LFb07-A.5		4	70-80	1	1	1	**3**	Hypersulfidic medium clay		
LFc07-A.1	c	1	0-25	1	1	1	**3**	Hypersulfidic sand	Hypersulfidic subaqueous clay soil (clay)	**High**
LFc07-A.2		2	25-40	0	1	1	2	Hypersulfidic sandy clay loam		
LFc07-A.3		3	40-55	1	1	1	**3**	Hypersulfidic silty clay		
LFc07-A.4		4	55-70	1	1	1	**3**	Hypersulfidic silty clay		
LFd07-A.1	d	1	0-18	0	0	1	1	Hyposulfidic sandy loam	Hypersulfidic subaqueous clay soil (clay)	**Medium**
LFd07-A.2		2	18-50	1	1	1	**3**	Hypersulfidic loamy clay		
LFd07-A.3		3	50-69	0	0	1	1	Hyposulfidic loamy clay		
LFd07-A.4		5	69-76	0	0	0	0	Hyposulfidic calcareous clay		
LFe07-A.1	e	1	0-12	0	1	1	2	Hypersufilidic organic clay	Hypersulfidic subaqueous clay soil (clay)	**Medium**
LFe07-A.2		2	12-22	1	1	1	**3**	Hypersufilidic loamy sand		
LFe07-A.3		3	22-48	0	1	1	2	Hypersufilidic sandy clay		
LFe07-A.5		5	66-68	1	0	1	2	Hyposulfidic heavy clay		
LFf07-A.1	f	1	0-8	0	1	1	2	Hypersufilidic loamy sand	Hypersulfidic subaqueous clay soil (clay)	**Medium**
LFf07-A.2		2	8-18	0	1	1	2	Hypersufilidic loamy sand		
LFf07-A.3		3	18-38	1	1	1	**3**	Hypersufilidic loamy sand		
LFf07-A.4		4	38-62	1	1	1	**3**	Hypersufilidic heavy clay		
LFf07-A.5		5	62-84	1	1	1	**3**	Hypersufilidic heavy clay		
LFg07-A.1	g	1	0-16	0	1	1	2	Hypersufilidic loamy sand	Hypersulfidic subaqueous clay soil (clay)	**Medium**
LFg07-A.2		NC	16-31	1	1	1	**3**	Hypersufilidic loamy sand		
LFg07-A.3		4	31-55	1	1	1	**3**	Hypersufilidic heavy clay		
LFg07-A.4		5	55-70	1	1	1	**3**	Hypersufilidic heavy calcareous clay		

Table A-14. Summary of temporal changes in ASS Classification, acidification hazard ^{1}(**H** = High; **M** = medium; **L** = Low; **VL** = Very Low), site condition and profile chemistry and morphology (Refer to previous two figures and table)

Sampling	^{1}ASS Classification & ^{2}Acidification hazard	Site photographs	Notes
Pre-monitoring **Drought** **Summer** **2008 (pm)**	**Sulfuric (H)**		During the extreme drought period (2007 to 2009) the partial drying of the lake caused Sulfuric subaqueous soil to transform to Sulfuric (clay) soil. Inundation, following winter 2010, caused the formation of Hypersulfidic subaqueous soil.
Drought **End winter** **2009 (a)**	**Sulfuric clay (H)**		
Drought **End summer** **2010 (b)**	**Sulfuric clay (H)**		
Post-drought **Summer** **2011 (c)**	**Hypersulfidic subaqueous clay (H)**		
Post-drought **Winter** **2011 (d)**	**Hypersulfidic subaqueous clay (M)**		
Post-drought **Start summer** **2011/12 (e)**	**Hypersulfidic subaqueous clay (M)**		
Post-drought **Start winter** **2012 (f)**	**Hypersulfidic subaqueous clay (M)**		
Post-drought **Summer** **2013 (g)**	**Hypersulfidic subaqueous clay (M)**		

A.7 LF08: Meningie

LF08-A

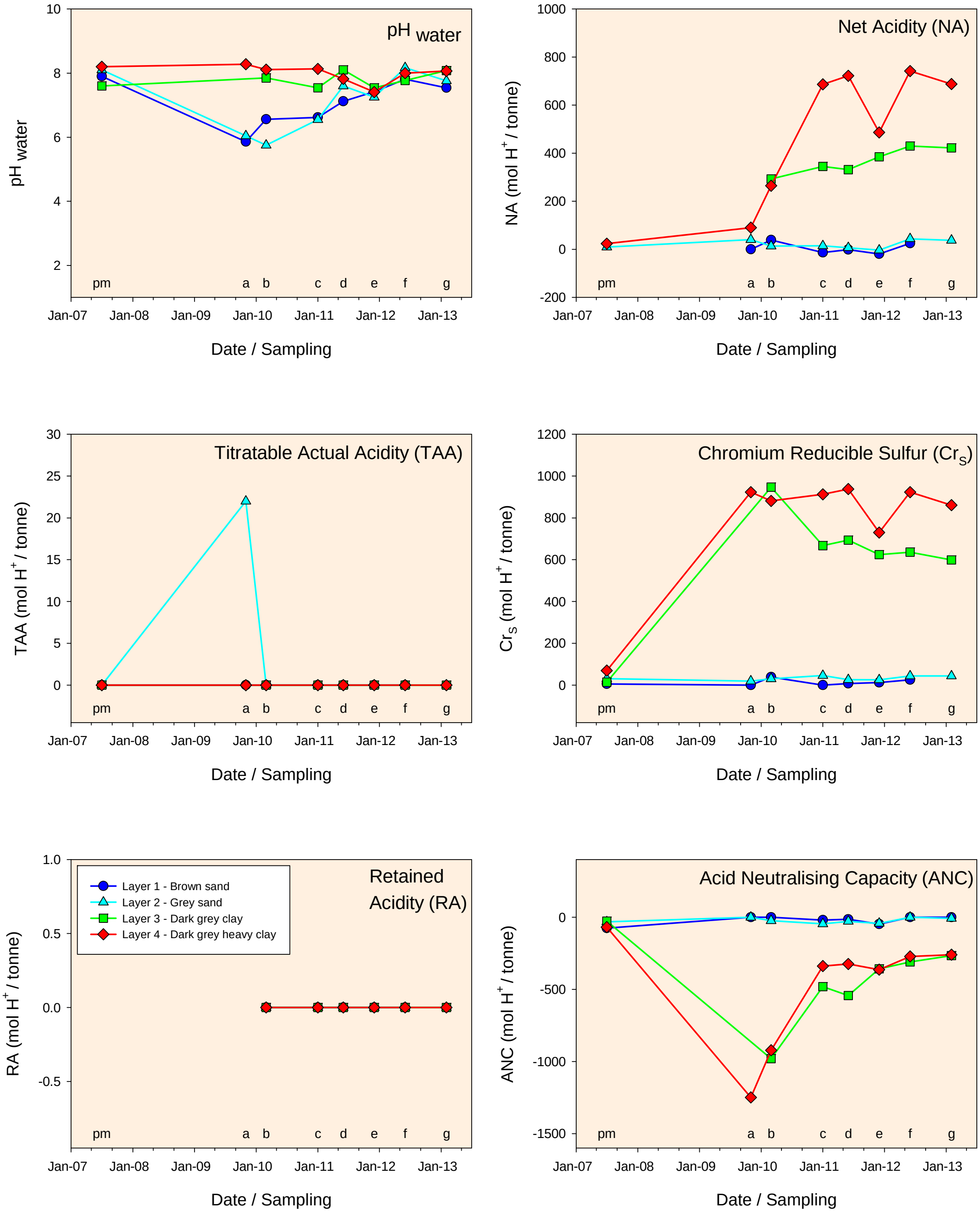


Figure A-15. Plots describing the location and quantity of acidity and acid neutralisation capacity within the soil profile and how this alters through time in response to drought and subsequent reflooding

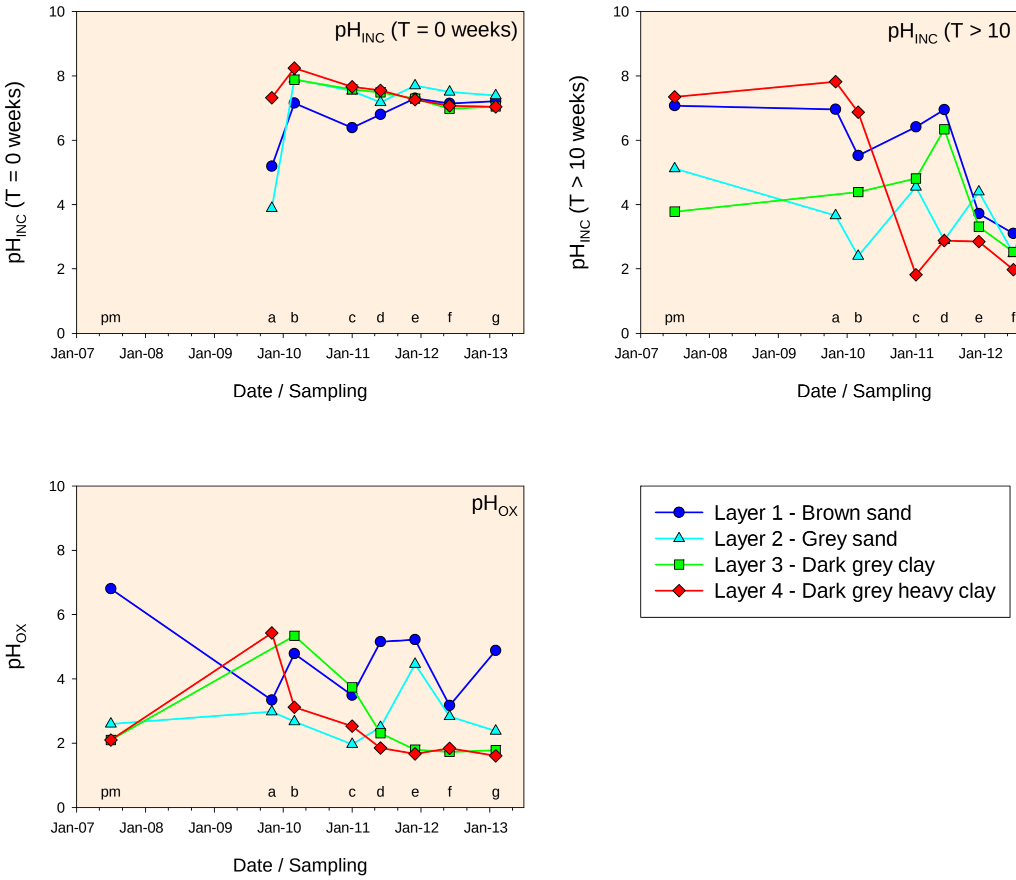


Figure A-16. Plots describing the acidification potential of soil material from different depths in the soil profile through time

Table A-15 Summary of acidification potential, ASS material classification, ASS subtype classification and acidification hazard (* indicates sulfuric soil material). The soil texture in brackets following the ASS subtype classification indicates the dominant texture of the profile. The layer number refers to soil layers and corresponding data that are plotted in the previous two figures. NC: non-continuous soil layers that were not encountered during the majority of samplings

Sample	Sampling	Layer	Depth (cm)	pH_{OX} < 2.5	pH_{INC} < 4.0	NA > 0	Acidification potential	ASS material classification	ASS subtype	Acidification hazard
LF08-A										
AT 4.1	pm	1	0-5	0	0	0	0	Sand	Hypersulfidic subaqueous soil (sand)	**Medium**
AT 4.2		2	5-10	0	0	1	1	Hyposulfidic sand		
AT 4.3		3	10-30	1	1	0	2	Hypersulfidic sand		
AT 4.4		4	30-60	1	0	1	2	Hyposulfidic clayey sand		
AT 4.5		5	60-70	1	0	1	2	Hyposulfidic heavy clay		
LFa08-A.1	a	1	0-8	0	0	0	0	Hyposulfidic sand	Hypersulfidic clay soil (clay)	**Medium**
LFa08-A.2		2	8-18	0	1	1	2	Hypersulfidic sand		
LFa08-A.3		NC	18-25	0	1	1	2	Hypersulfidic sand		
LFa08-A.4		4	25-50	0	0	1	1	Hyposulfidic medium clay		
LFa08-A.5		NC	50-60	1	1	1	**3**	Hypersulfidic medium clay		
LFb08-A.1	b	1	0-18	0	0	1	1	Hyposulfidic sand	Hypersulfidic clay soil (clay)	**Medium**
LFb08-A.2		2	18-28	0	1	1	2	Hypersulfidic sand		
LFb08-A.3		3	28-45	0	0	1	1	Hyposulfidic medium clay		
LFb08-A.4		4	45-60	0	0	1	1	Hyposulfidic heavy clay		
LFc08-A.1	c	1	0-12	0	0	0	0	sand	Hypersulfidic subaqueous clay soil (clay)	**Medium**
LFc08-A.2		2	12-28	1	0	1	2	Hyposulfidic sand		
LFc08-A.3		3	28-60	0	0	1	1	Hyposulfidic clay		
LFc08-A.4		4	60-78	0	1	1	2	Hypersulfidic clay		
LFd08-A.1	d	1	0-12	0	0	0	0	Hyposulfidic sand	Hypersulfidic subaqueous clay soil (clay)	**Medium**
LFd08-A.2		2	12-21	0	1	1	2	Hypersulfidic loamy sand		
LFd08-A.3		3	21-33	1	0	1	2	Hyposulfidic clay		
LFd08-A.4		4	33-60	1	1	1	**3**	Hypersulfidic clay		
LFe08-A.1	e	1	0-8	0	1	0	1	Hypersufilidic sand	Hypersulfidic subaqueous clay soil (clay)	**Medium**
LFe08-A.2		2	8-26	0	0	0	0	Hyposulfidic sand		
LFe08-A.3		3	26-45	1	1	1	**3**	Hypersufilidic heavy clay		
LFe08-A.4		4	45-58	1	1	1	**3**	Hypersufilidic heavy clay		
LFf08-A.1	f	1	0-8	0	1	1	2	Hypersufilidic loamy sand	Hypersulfidic subaqueous clay soil (clay)	**Medium**
LFf08-A.2		2	8-32	0	1	1	2	Hypersufilidic loamy sand		
LFf08-A.3		3	32-52	1	1	1	**3**	Hypersufilidic heavy clay		
LFf08-A.4		4	52-86	1	1	1	**3**	Hypersufilidic heavy clay		
LFg08-A.1	g	NC	0-10	0	0	0	0	Hyposulfidic monosulfidic gel	Hypersulfidic subaqueous clay soil (clay)	**Medium**
LFg08-A.3		2	18-50	1	0	1	2	Hyposulfidic loamy sand		
LFg08-A.4		3	50-66	1	1	1	**3**	Hypersufilidic heavy clay		
LFg08-A.5		4	66-76	1	1	1	**3**	Hypersufilidic heavy clay		

Table A-16. Summary of temporal changes in ASS Classification, acidification hazard [1](**H** = High; **M** = medium; **L** = Low; **VL** = Very Low), site condition and profile chemistry and morphology (Refer to previous two figures and table)

Sampling	[1]ASS Classification & [2]Acidification hazard	Site photographs	Notes
Pre-monitoring Pre-drought Winter 2007 (pm)	**Hypersulfidic subaqueous (M)**		During the extreme drought period (2007 to 2009) the partial drying of the lake caused Hypersulfidic subaqueous soil to transform to Hypersulfidic clay soil. Inundation, following winter 2010, caused the formation of Hypersulfidic subaqueous clay soil.
Drought End winter 2009 (a)	**Hypersulfidic clay (M)**		
Drought End summer 2010 (b)	**Hypersulfidic clay (M)**		
Post-drought Summer 2011 (c)	**Hypersulfidic subaqueous clay (M)**		
Post-drought Winter 2011 (d)	**Hypersulfidic subaqueous clay (M)**		
Post-drought Start summer 2011/12 (e)	**Hypersulfidic subaqueous clay (M)**		
Post-drought Start winter 2012 (f)	**Hypersulfidic subaqueous clay (M)**		
Post-drought Summer 2013 (g)	**Hypersulfidic subaqueous clay (M)**		

LF08-B

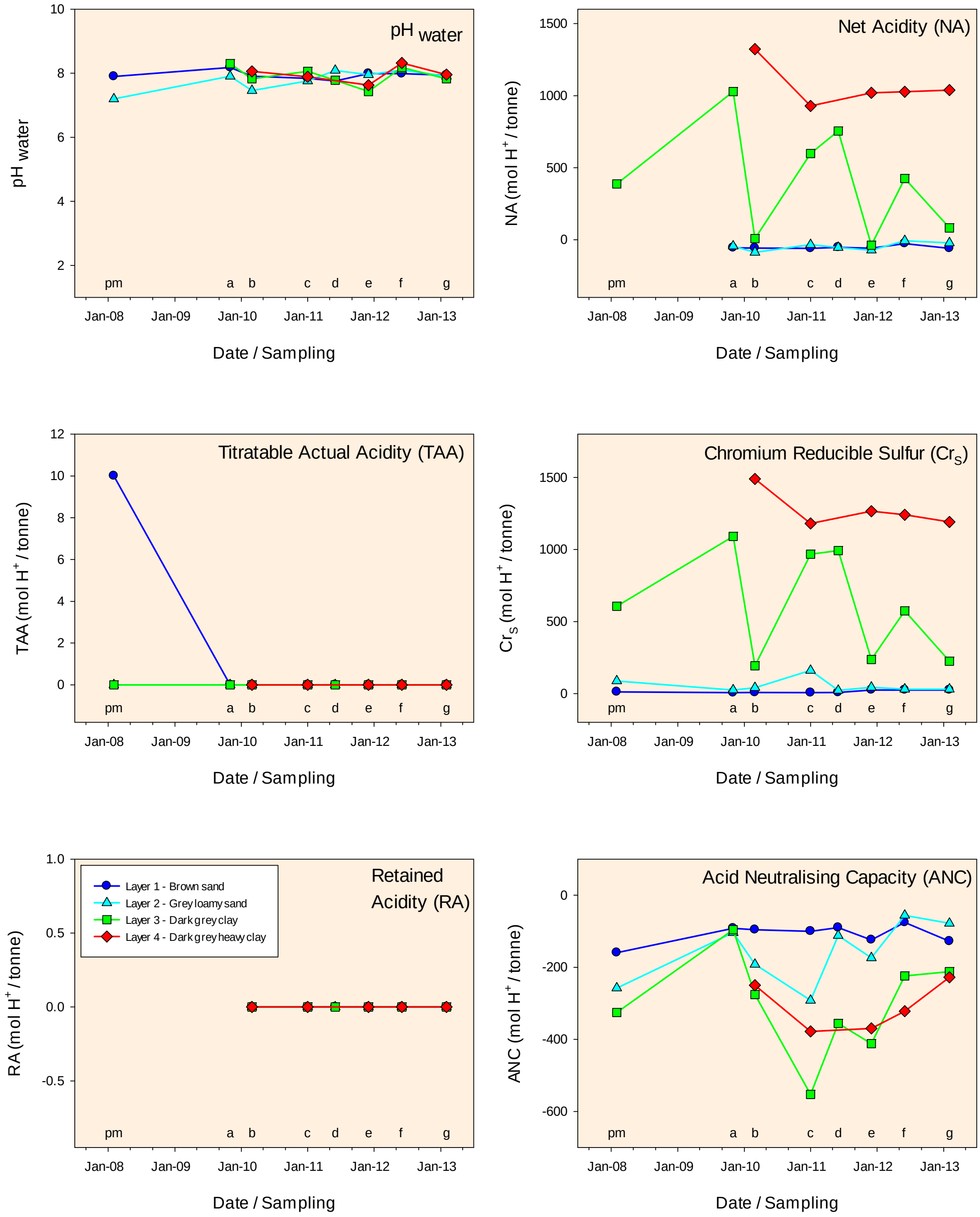


Figure A-17. Plots describing the location and quantity of acidity and acid neutralisation capacity within the soil profile and how this alters through time in response to drought and subsequent reflooding

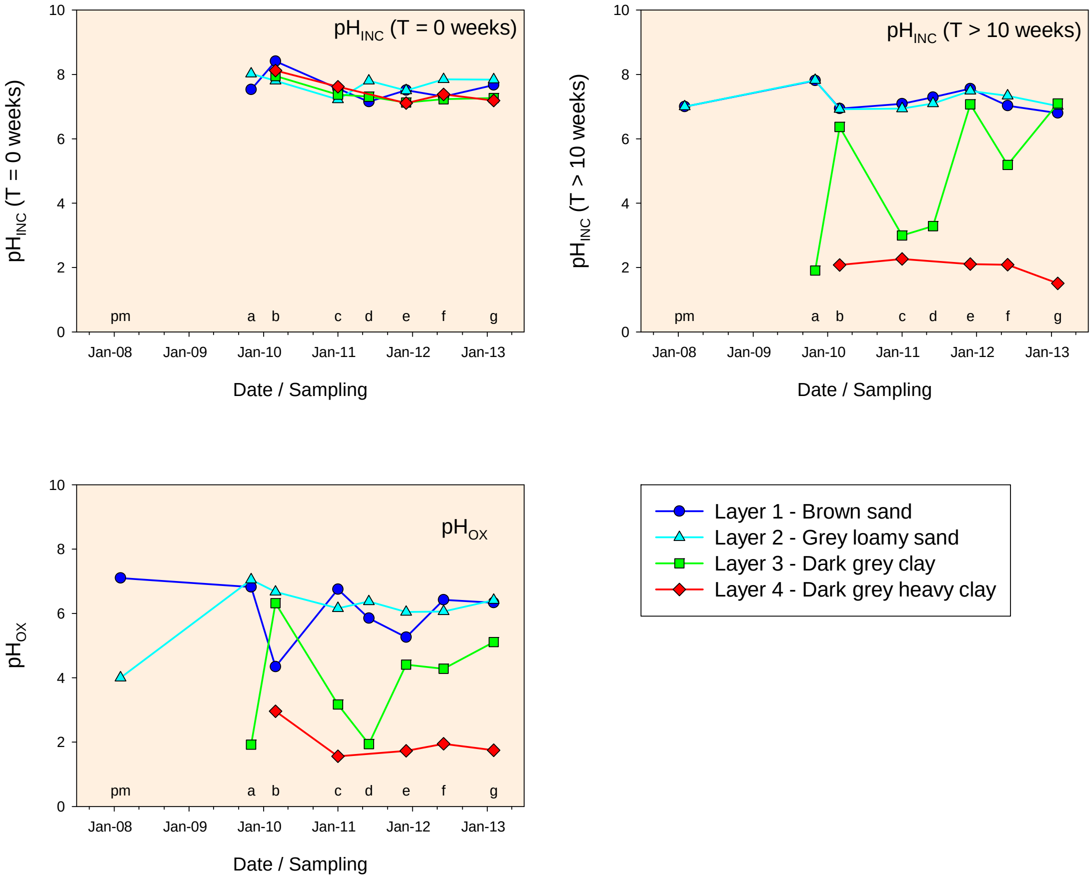


Figure A-18. Plots describing the acidification potential of soil material from different depths in the soil profile through time

Table A-17 Summary of acidification potential, ASS material classification, ASS subtype classification and acidification hazard (* indicates sulfuric soil material). The soil texture in brackets following the ASS subtype classification indicates the dominant texture of the profile. The layer number refers to soil layers and corresponding data that are plotted in the previous two figures. NC: non-continuous soil layers that were not encountered during the majority of samplings

Sample	Sampling	Layer	Depth (cm)	pH_{OX} < 2.5	pH_{INC} < 4.0	NA > 0	Acidification potential	ASS material classification	ASS subtype	Acidification hazard
LF08-B										
AT 17.1	pm	NC	0-1	0	0	0	0	Sand	Hyposulfidic subaqueous clay soil (clay)	Low
AT 17.2		1	1-10	0	0	0	0	Hyposulfidic sand		
AT 17.3		2	10-20	0	0	0	0	Hyposulfidic sandy clay		
LFa08-B.1	a	1	0-10	0	0	0	0	Hyposulfidic sand	Hypersulfidic clay soil (sand)	Medium
LFa08-B.2		2	10-20	0	0	0	0	Hyposulfidic sand		
LFa08-B.3		3	20-35	0	0	0	0	Hyposulfidic sand		
LFa08-B.4		4	35-55	1	1	1	3	Hypersulfidic medium clay		
LFb08-B.1	b	1	0-25	0	0	0	0	Hyposulfidic sand	Hypersulfidic clay soil (clay)	Medium
LFb08-B.2		2	25-32	0	0	0	0	Hyposulfidic sand		
LFb08-B.3		3	32-45	0	0	1	1	Hyposulfidic sandy clay		
LFb08-B.4		4	45-65	0	1	1	2	Hypersulfidic light clay		
LFc08-B.1	c	1	0-20	0	0	0	0	Hyposulfidic sand	Hypersulfidic subaqueous clay soil (clay)	Medium
LFc08-B.2		2	20-33	0	0	0	0	Hyposulfidic sandy clay		
LFc08-B.3		3	33-45	0	1	1	2	Hypersulfidic sandy clay		
LFc08-B.4		4	45-65	1	1	1	3	Hypersulfidic clay		
LFd08-B.1	d	1	0-16	0	0	0	0	Hyposulfidic sand	Hypersulfidic subaqueous clay soil (clay)	Medium
LFd08-B.2		2	16-23	0	0	0	0	Hyposulfidic loamy sand		
LFd08-B.3		3	23-56	1	1	1	3	Hypersulfidic clay		
LFe08-B.1	e	1	0-20	0	0	0	0	Hyposulfidic sand	Hypersulfidic subaqueous clay soil (clay)	Medium
LFe08-B.2		2	20-30	0	0	0	0	Hyposulfidic loamy sand		
LFe08-B.3		3	30-37	0	0	0	0	Hyposulfidic heavy clay		
LFe08-B.4		4	37-70	1	1	1	3	Hypersufilidic heavy clay		
LFf08-B.1	f	1	0-23	0	0	0	0	Hyposulfidic loamy sand	Hypersulfidic subaqueous clay soil (clay)	Medium
LFf08-B.2		2	23-30	0	0	0	0	Hyposulfidic loamy sand		
LFf08-B.3		3	30-35	0	0	1	1	Hyposulfidic heavy clay		
LFf08-B.4		4	35-77	1	1	1	3	Hypersufilidic heavy clay		
LFg08-B.1	g	1	0-18	0	0	0	0	Hyposulfidic silty sand	Hypersulfidic subaqueous clay soil (clay)	Medium
LFg08-B.2		2	18-26	0	0	0	0	Hyposulfidic loamy sand		
LFg08-B.3		3	26-32	0	0	1	1	Hyposulfidic heavy clay		
LFg08-B.4		4	32-65	1	1	1	3	Hypersufilidic heavy clay		

Table A-18. Summary of temporal changes in ASS Classification, acidification hazard [1](**H** = High; **M** = medium; **L** = Low; **VL** = Very Low), site condition and profile chemistry and morphology (Refer to previous two figures and table)

Sampling	[1]ASS Classification & [2]Acidification hazard	Site photographs	Notes
Pre-monitoring Drought Summer 2008 (pm)	**Hyposulfidic subaqueous clay (L)**		During the extreme drought period (2007 to 2009) the partial drying of the lake caused Hyposulfidic subaqueous clay soil to transform to Hypersulfidic clay soil. Inundation, following winter 2010, caused the formation of Hypersulfidic subaqueous clay soil.
Drought End winter 2009 (a)	**Hypersulfidic clay (M)**		
Drought End summer 2010 (b)	**Hypersulfidic clay (M)**		
Post-drought Summer 2011 (c)	**Hypersulfidic subaqueous clay (M)**		
Post-drought Winter 2011 (d)	**Hypersulfidic subaqueous clay (M)**		
Post-drought Start summer 2011/12 (e)	**Hypersulfidic subaqueous clay (M)**		
Post-drought Start winter 2012 (f)	**Hypersulfidic subaqueous clay (M)**		
Post-drought Summer 2013 (g)	**Hypersulfidic subaqueous clay (M)**		

A.8 LF10: Campbell Park

LF10-A

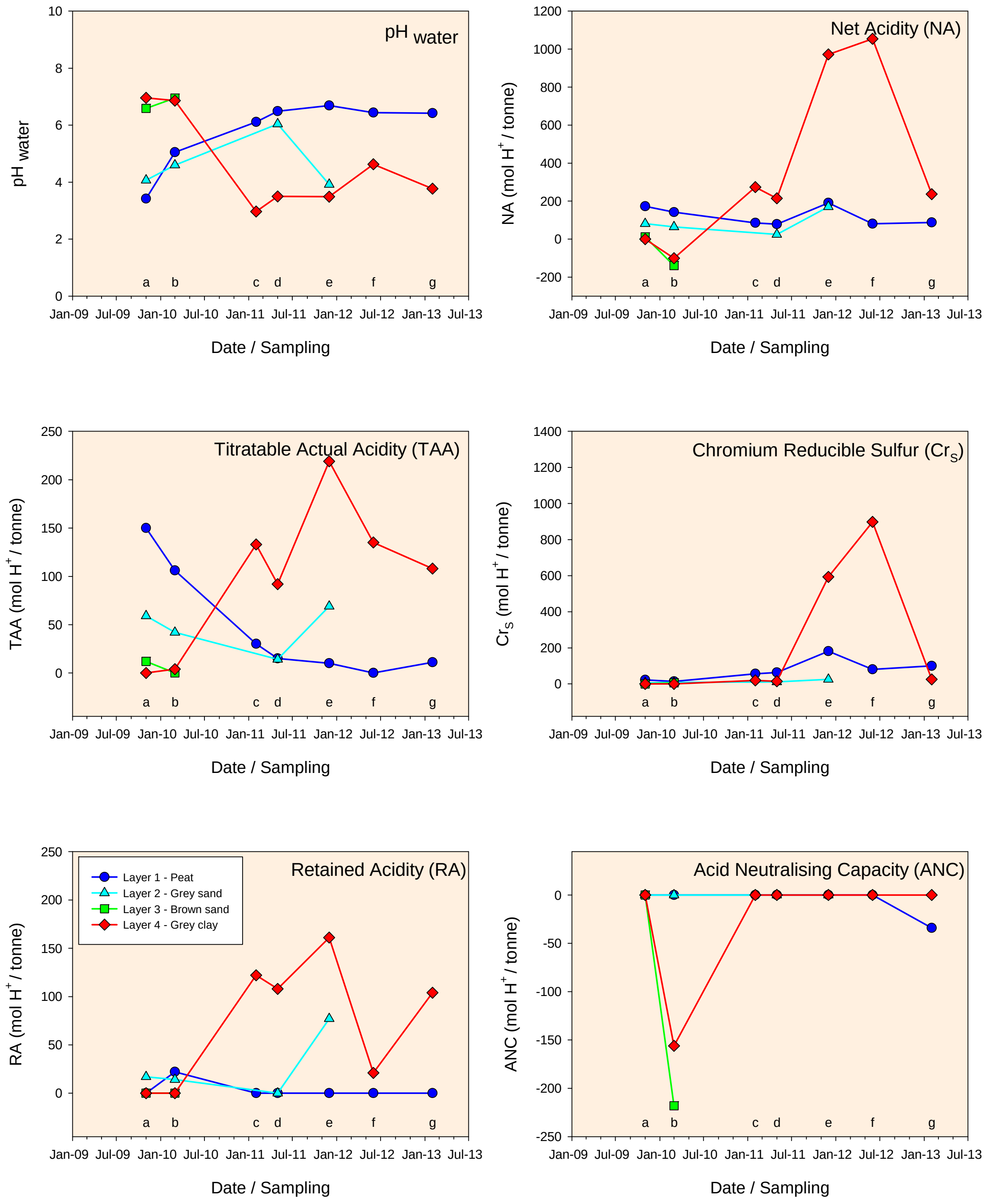


Figure A-19. Plots describing the location and quantity of acidity and acid neutralisation capacity within the soil profile and how this alters through time in response to drought and subsequent reflooding

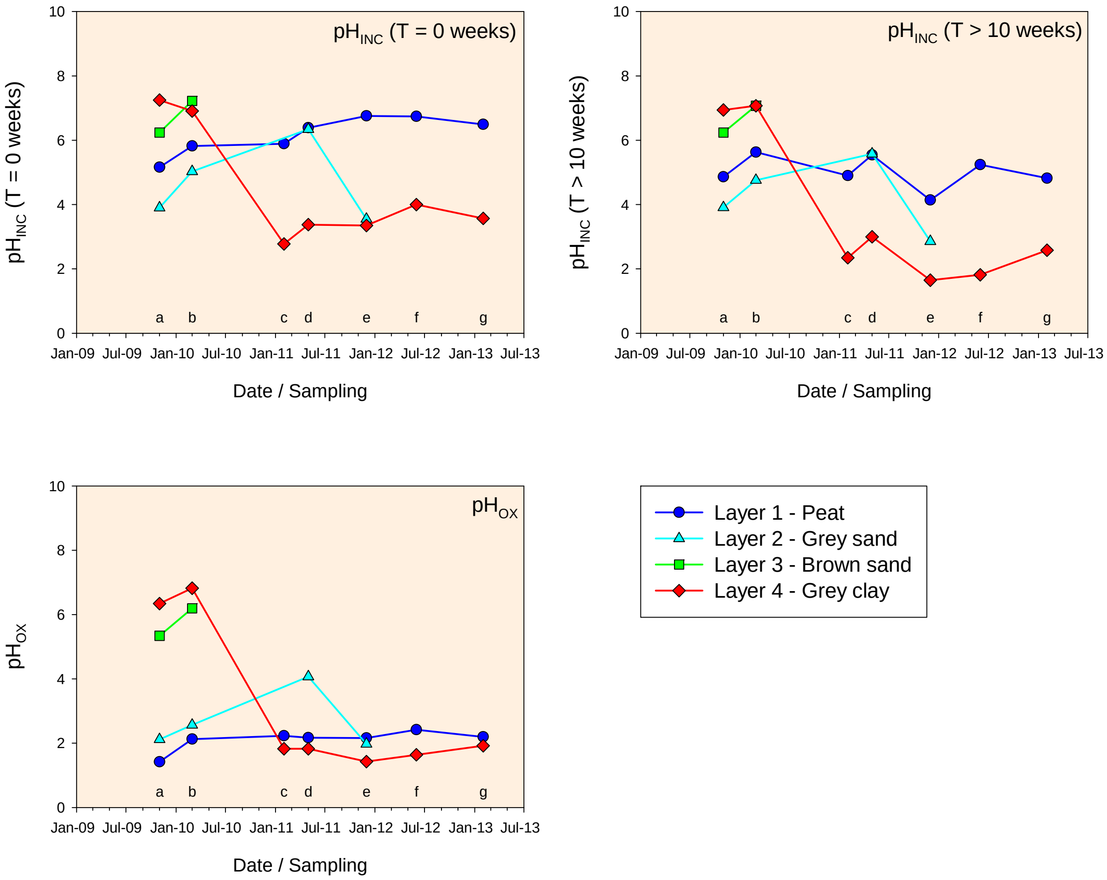
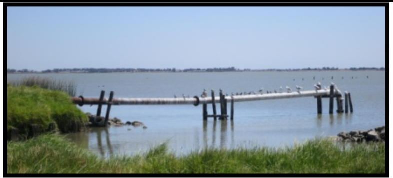


Figure A-20. Plots describing the acidification potential of soil material from different depths in the soil profile through time

Table A-19 Summary of acidification potential, ASS material classification, ASS subtype classification and acidification hazard (* indicates sulfuric soil material). The soil texture in brackets following the ASS subtype classification indicates the dominant texture of the profile. The layer number refers to soil layers and corresponding data that are plotted in the previous two figures. NC: non-continuous soil layers that were not encountered during the majority of samplings

Sample	Sampling	Layer	Depth (cm)	pH_{OX} < 2.5	pH_{INC} < 4.0	NA > 0	Acidification potential	ASS material classification	ASS subtype	Acidification hazard
LF10-A										
LFa10-A.1	a	1	0-50	1	0	1	2*	Sulfuric peat	Sulfuric organic soil (organic)	**High**
LFa10-A.2		2	50-75	1	1	1	**3**	Hyposulfidic sand		
LFa10-A.3		3	75-80	0	0	1	1	Hyposulfidic sand		
LFa10-A.4		4	80-100	0	0	0	0	Hyposulfidic heavy clay		
LFb10-A.1	b	1	0-50	1	0	1	2	Hyposulfidic peat	Hyposulfidic organic soil (organic)	**Medium**
LFb10-A.2		2	50-75	0	0	1	1	Hyposulfidic loamy sand		
LFb10-A.3		3	75-80	0	0	0	0	Hyposulfidic loamy sand		
LFb10-A.4		4	80-100	0	0	0	0	Hyposulfidic heavy clay		
LFc10-A.1	c	1	0-18	1	0	1	2	Hyposulfidic sandy organic clay	Sulfuric subaqueous organic soil (clay)	**High**
LFc10-A.2		NC	18-36	0	0	1	1	Hyposulfidic clay		
LFc10-A.3		4	36-66	1	1	1	**3***	Sulfuric clay		
LFc10-A.4		NC	66-80	1	1	1	**3***	Sulfuric clay		
LFd10-A.1	d	1	0-12	1	0	1	2	Hyposulfidic hemic peat	Sulfuric subaqueous organic soil (clay)	**High**
LFd10-A.2		2	12-19	0	0	1	1	Hyposulfidic sand		
LFd10-A.3		4	19-63	1	1	1	**3***	Sulfuric clay		
LFe10-A.1	e	1	0-10	1	0	1	2	Hyposulfidic hemic peat	Sulfuric subaqueous organic soil (clay)	**High**
LFe10-A.2		2	10-20	1	1	1	**3**	Sulfuric clayey sand		
LFe10-A.3		NC	20-57	1	1	1	**3**	Sulfuric heavy clay		
LFe10-A.4		4	57-65	1	1	1	**3**	Sulfuric heavy clay		
LFf10-A.1	f	1	0-12	1	0	1	2	Hyposulfidic hemic peat	Hypersulfidic subaqueous organic soil (clay)	**High**
LFf10-A.2		NC	12-21	0	0	0	0	Hyposulfidic hemic peat		
LFf10-A.3		NC	21-53	1	1	1	**3**	Hypersufilidic heavy clay		
LFf10-A.4		4	53-86	1	1	1	**3**	Hypersufilidic heavy clay		
LFg10-A.1	g	1	0-16	1	0	1	2	Hyposulfidic peat	Sulfuric subaqueous organic soil (clay)	**High**
LFg10-A.2		NC	16-26	0	0	1	1	Hyposulfidic sandy clay		
LFg10-A.3		4	26-50	1	1	1	**3***	Sulfuric heavy clay		
LFg10-A.4		NC	50-69	1	1	1	**3***	Sulfuric heavy clay		

Table A-20. Summary of temporal changes in ASS Classification, acidification hazard [1](**H** = High; **M** = medium; **L** = Low; **VL** = Very Low), site condition and profile chemistry and morphology (Refer to previous two figures and table)

Sampling	[1]ASS Classification & [2]Acidification hazard	Site photographs	Notes
Drought End winter 2009 (a)	**Sulfuric* organic (H)**		During the entire extreme drought period (2007 to 2009) this site remained a Sulfuric organic soil. Spatial variability meant that this material classified as Hyposulfidic organic soil in 2010. Inundation, following winter 2010, caused the formation of Sulfuric subaqueous organic soil. As the site was on the extreme margin of the lake, seasonal wetting and drying meant that soil material was regularly dried resulting in the formation of both Hypersulfidic and Sulfuric subaqueous soil.
Drought End summer 2010 (b)	**Hyposulfidic organic (M)**		
Post-drought Summer 2011 (c)	**Sulfuric subaqueous organic (H)**		
Post-drought Winter 2011 (d)	**Sulfuric subaqueous organic (H)**		
Post-drought Start summer 2011/12 (e)	**Sulfuric subaqueous organic (H)**		
Post-drought Start winter 2012 (f)	**Hypersulfidic subaqueous organic (H)**		
Post-drought Summer 2013 (g)	**Sulfuric subaqueous organic (H)**		

LF10-C

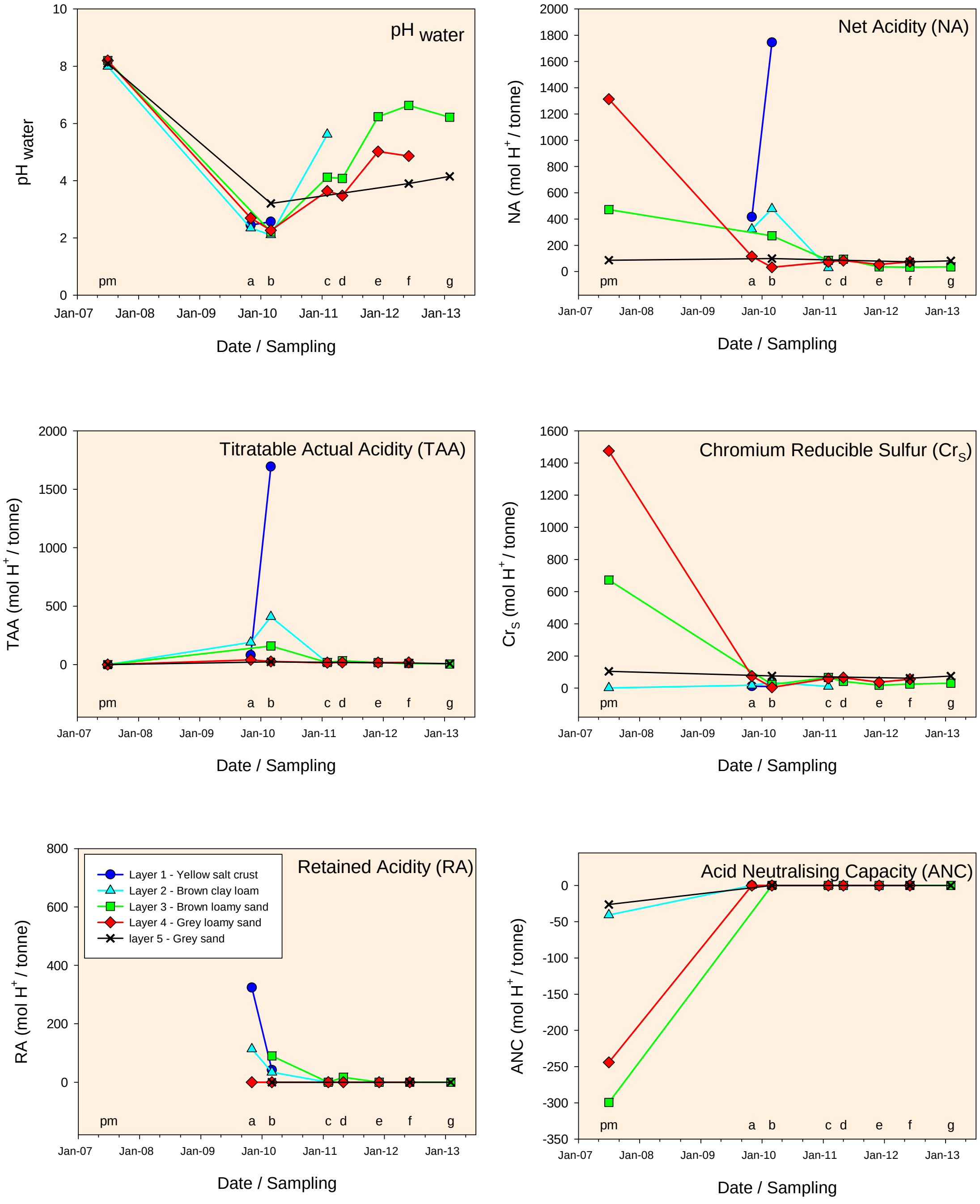


Figure A-21. Plots describing the location and quantity of acidity and acid neutralisation capacity within the soil profile and how this alters through time in response to drought and subsequent reflooding

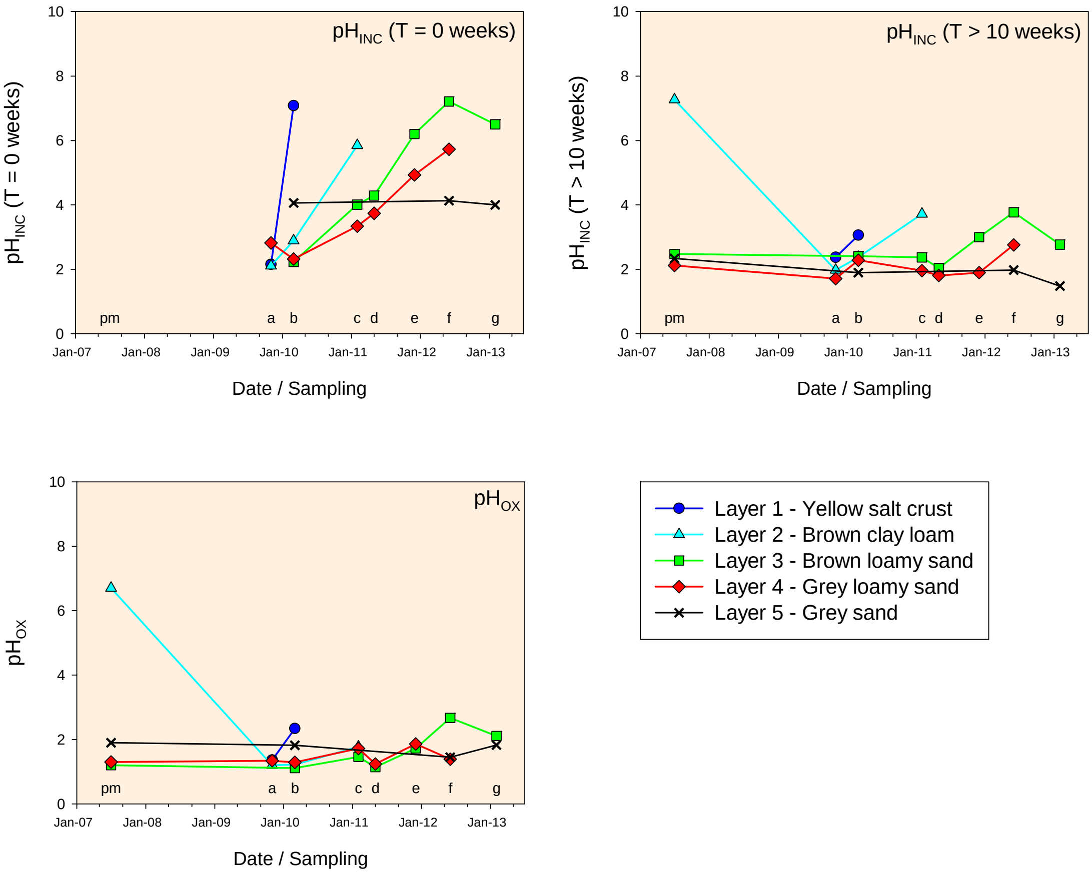
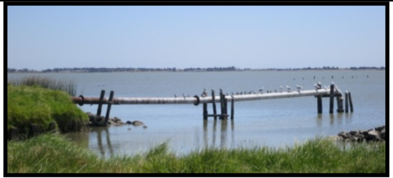


Figure A-22. Plots describing the acidification potential of soil material from different depths in the soil profile through time

Table A-21 Summary of acidification potential, ASS material classification, ASS subtype classification and acidification hazard (* indicates sulfuric soil material). The soil texture in brackets following the ASS subtype classification indicates the dominant texture of the profile. The layer number refers to soil layers and corresponding data that are plotted in the previous two figures. NC: non-continuous soil layers that were not encountered during the majority of samplings

Sample	Sampling	Layer	Depth (cm)	pH_{OX} < 2.5	pH_{INC} < 4.0	NA > 0	Acidification potential	ASS material classification	ASS subtype	Acidification hazard
LF10-C										
AT 7.1	pm	2	0-5	0	0	0	0	Sand	Hypersulfidic subaqueous clay soil (sand)	**High**
AT 7.2		3	5-20	1	1	1	**3**	Hypersulfidic heavy clay		
AT 7.3		4	20-40	1	1	1	**3**	Hypersulfidic heavy clay		
AT 7.4		5	40-50	1	1	1	**3**	Hypersulfidic sand		
AT 7.5		NC	50-75	1	1	1	**3**	Hypersulfidic sand		
LFa10-C.1	a	1	0-0.5	1	1	1	**3***	Sulfuric crust	Sulfuric clay soil (sand)	**High**
LFa10-C.2		2	0.5-5	1	1	1	**3***	Sulfuric silty clay		
LFa10-C.3		NC	5-20	1	1	1	**3***	Sulfuric sand		
LFa10-C.4		4	20-50	1	1	1	**3***	Sulfuric clayey sand		
LFa10-C.5		NC	50-80	1	1	1	**3***	Sulfuric medium clay		
LFb10-C.1	b	1	0-0.5	1	1	1	**3***	Sulfuric sand	Sulfuric clay soil (sand)	**High**
LFb10-C.2		2	0.5-5	1	1	1	**3***	Sulfuric clay loam		
LFb10-C.3		3	5-20	1	1	1	**3***	Sulfuric light clay		
LFb10-C.4		4	20-35	1	1	1	**3***	Sulfuric sand		
LFb10-C.5		NC	35-50	1	1	1	**3***	Sulfuric loamy sand		
LFb10-C.6		5	50-80	1	1	1	**3***	Sulfuric sand		
LFc10-C.1	c	2	0-7	1	1	1	**3**	Hypersulfidic sandy clay loam	Sulfuric subaqueous soil (sand)	**High**
LFc10-C.2		3	7-29	1	1	1	**3**	Hypersulfidic sandy clay loam		
LFc10-C.3		4	29-45	1	1	1	**3***	Sulfuric loamy sand		
LFc10-C.4		NC	45-70	1	1	1	**3***	Sulfuric loamy sand		
LFd10-C.1	d	NC	0-10	1	1	1	**3**	Hypersulfidic clay	Sulfuric subaqueous soil (sand)	**High**
LFd10-C.2		3	10-29	1	1	1	**3**	Hypersulfidic loamy sand		
LFd10-C.3		4	29-50	1	1	1	**3***	Sulfuric loamy sand		
LFd10-C.4		NC	50-70	1	1	1	**3**	Hypersulfidic loamy sand		
LFe10-C.1	e	NC	0-5	1	0	1	2	Hyposulfidic heavy clay	Hypersulfidic subaqueous soil (sand)	**High**
LFe10-C.2		3	5-18	1	1	1	**3**	Hypersufilidic loamy sand		
LFe10-C.3		4	18-30	1	1	1	**3**	Hypersufilidic loamy sand		
LFe10-C.4		NC	30-45	1	1	1	**3**	Hypersufilidic loamy sand		
LFf10-C.1	f	3	0-18	0	1	1	2	Hypersufilidic loamy sand	Hypersulfidic subaqueous soil (sand)	**High**
LFf10-C.2		NC	18-23	1	1	1	**3**	Hypersufilidic organic clay		
LFf10-C.3		4	23-40	1	1	1	**3**	Hypersufilidic loamy sand		
LFf10-C.4		5	40-70	1	1	1	**3***	Sulfuric sand		
LFg10-C.1	g	3	0-15	1	1	1	**3**	Hypersufilidic clayey peat	Hypersulfidic subaqueous organic soil (sand)	**High**
LFg10-C.2		NC	15-32	1	1	1	**3**	Hypersufilidic clayey peat		
LFg10-C.3		4	32-72	1	1	1	**3**	Hypersufilidic sand		

Table A-22. Summary of temporal changes in ASS Classification, acidification hazard [1](**H** = High; **M** = medium; **L** = Low; **VL** = Very Low), site condition and profile chemistry and morphology (Refer to previous two figures and table)

Sampling	[1]ASS Classification & [2]Acidification hazard	Site photographs	Notes
Pre-monitoring Drought Summer 2008 (pm)	**Hypersulfidic subaqueous clay (H)**		During the extreme drought period (2007 to 2009) the partial drying of the lake caused the Hypersulfidic subaqueous soils to transform to Sulfuric soils. Inundation, following winter 2010, caused the formation of Sulfuric subaqueous soil. Prolonged inundation, for > 21 months resulted in the formation of Hypersulfidic subaqueous soil.
Drought End winter 2009 (a)	**Sulfuric* clay (H)**		
Drought End summer 2010 (b)	**Sulfuric* clay (H)**		
Post-drought Summer 2011 (c)	**Sulfuric subaqueous (H)**		
Post-drought Winter 2011 (d)	**Sulfuric subaqueous (H)**		
Post-drought Start summer 2011/12 (e)	**Hypersulfidic subaqueous (H)**		
Post-drought Start winter 2012 (f)	**Hypersulfidic subaqueous (H)**		
Post-drought Summer 2013 (g)	**Hypersulfidic subaqueous organic (H)**		

A.9 LF12: Loveday Bay

LF12-C

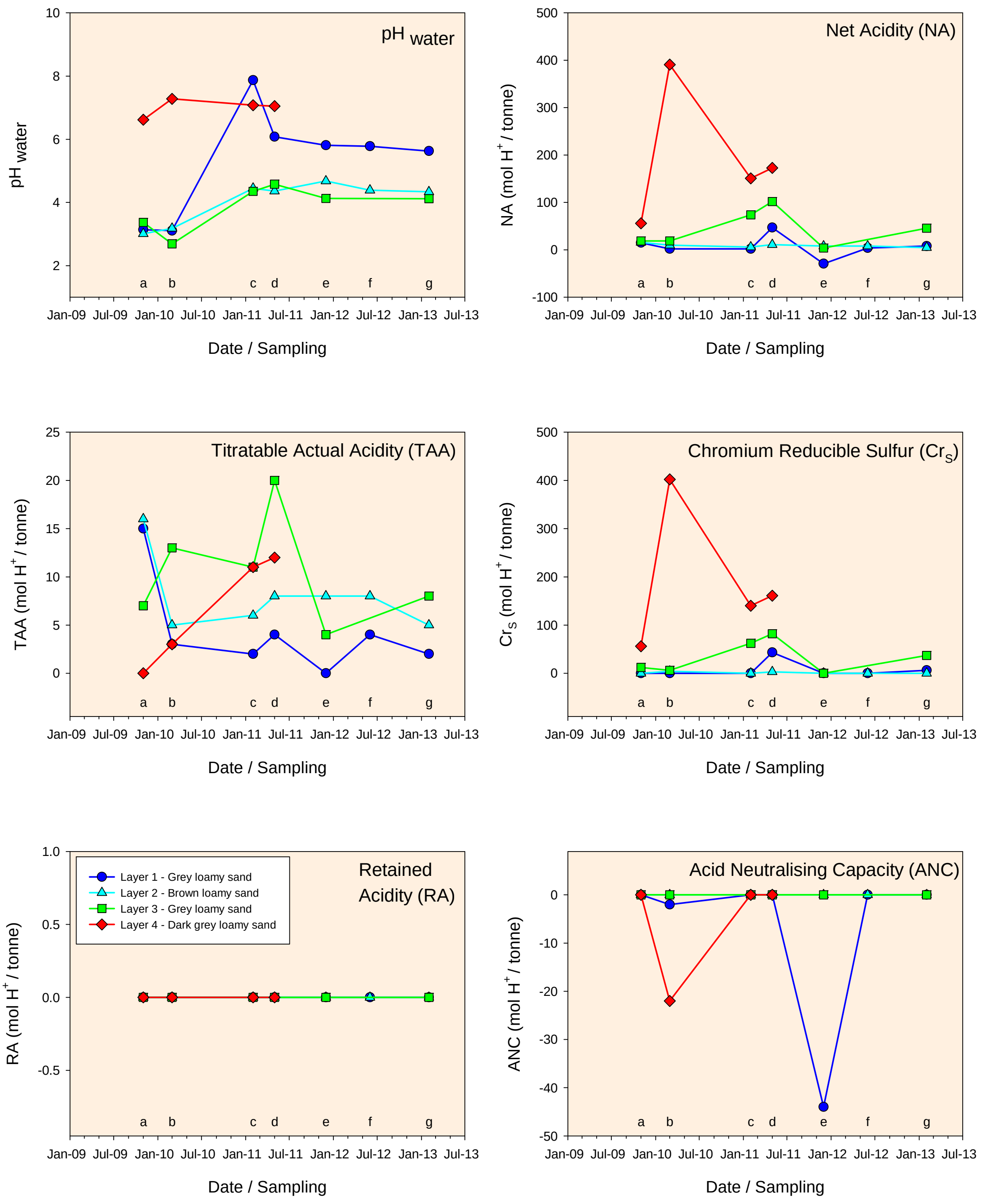


Figure A-23. Plots describing the location and quantity of acidity and acid neutralisation capacity within the soil profile and how this alters through time in response to drought and subsequent reflooding

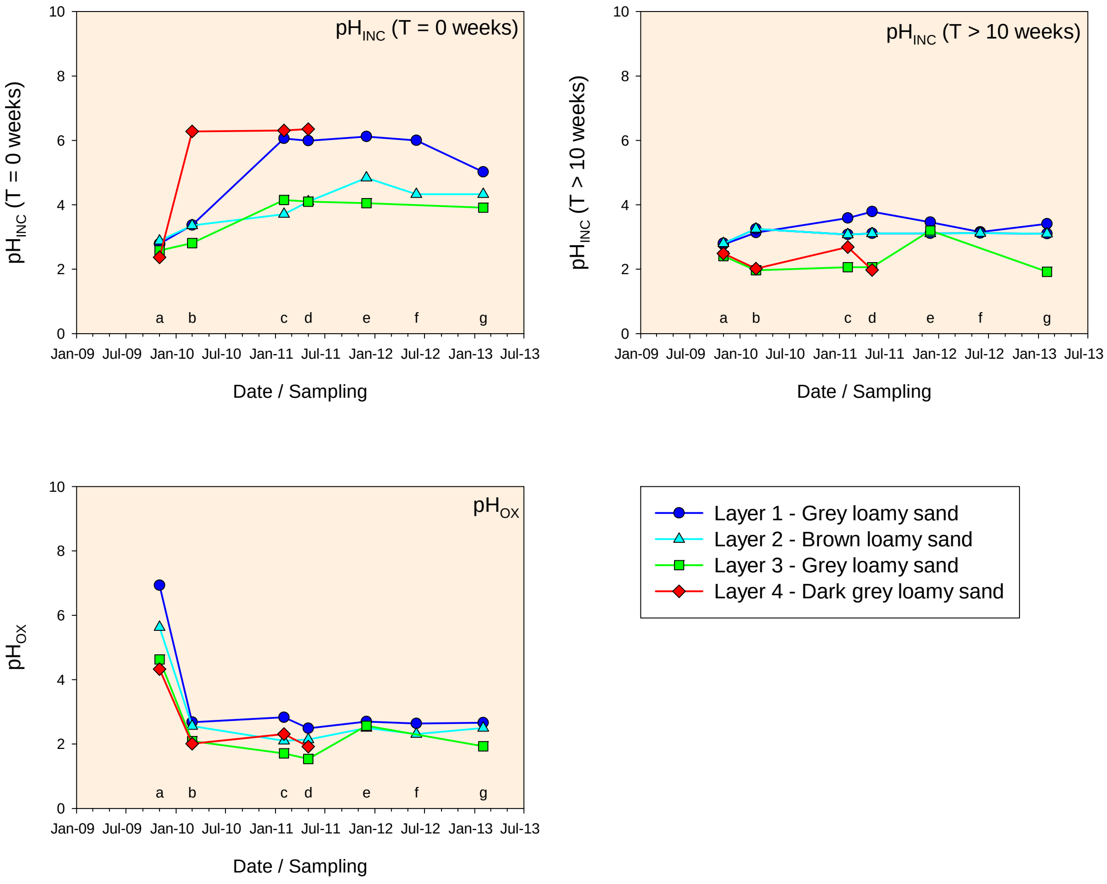


Figure A-24. Plots describing the acidification potential of soil material from different depths in the soil profile through time

Table A-23 Summary of acidification potential, ASS material classification, ASS subtype classification and acidification hazard (* indicates sulfuric soil material). The soil texture in brackets following the ASS subtype classification indicates the dominant texture of the profile. The layer number refers to soil layers and corresponding data that are plotted in the previous two figures. NC: non-continuous soil layers that were not encountered during the majority of samplings

Sample	Sampling	Layer	Depth (cm)	pH_{OX} < 2.5	pH_{INC} < 4.0	NA > 0	Acidification potential	ASS material classification	ASS subtype	Acidification hazard
LF12-C										
LFa12-C.1	a	NC	0-0.5	0	1	1	2*	Sulfuric crust	Sulfuric soil (sand)	**High**
LFa12-C.2		1	0.5-10	0	1	1	2*	Sulfuric sand		
LFa12-C.3		2	10-40	0	1	1	2*	Sulfuric sand		
LFa12-C.4		3	40-60	0	1	1	2*	Sulfuric sand		
LFa12-C.5		4	60-80	0	1	1	2	Hypersulfidic sand		
LFb12-C.1	b	1	0-10	0	1	1	2*	Sulfuric sand	Sulfuric soil (sand)	**High**
LFb12-C.2		2	10-23	0	1	1	2*	Sulfuric sand		
LFb12-C.3		NC	23-36	0	1	1	2*	Sulfuric sand		
LFb12-C.4		3	36-48	1	1	1	**3***	Sulfuric loamy sand		
LFb12-C.5		4	48-80	1	1	1	**3**	Hypersulfidic loamy sand		
LFc12-C.1	c	1	0-11	0	1	1	2	Loamy sand	Hypersulfidic subaqueous soil (sand)	**Medium**
LFc12-C.2		2	11-36	1	1	1	**3**	Loamy sand		
LFc12-C.3		3	36-50	1	1	1	**3**	Hypersulfidic loamy sand		
LFc12-C.4		4	50-66	1	1	1	**3**	Hypersulfidic loamy sand		
LFd12-C.1	d	1	0-12	1	1	1	**3**	Hypersulfidic loamy sand	Hypersulfidic subaqueous soil (sand)	**High**
LFd12-C.2		2	12-34	1	1	1	**3**	Loamy sand		
LFd12-C.3		3	34-50	1	1	1	**3**	Hypersulfidic loamy sand		
LFd12-C.4		4	50-64	1	1	1	**3**	Hypersulfidic loamy sand		
LFe12-C.1	e	1	0-13	0	1	0	1	Loamy sand	Hypersulfidic subaqueous soil (sand)	**Medium**
LFe12-C.2		2	13-32	0	1	1	2	Loamy sand		
LFe12-C.3		3	32-45	0	1	1	2	Loamy sand		
LFf12-C.1	f	1	0-10	0	1	1	2	Loamy sand	Hypersulfidic subaqueous soil (sand)	**Medium**
LFf12-C.2		2	10-40	1	1	1	**3**	Loamy sand		
LFf12-C.3		NC	40-77	1	1	1	**3**	Hypersufilidic loamy sand		
LFg12-C.1	g	1	0-13	0	1	1	2	Hypersufilidic sand	Hypersulfidic subaqueous soil (sand)	**Medium**
LFg12-C.2		2	13-40	0	1	1	2	Silty sand		
LFg12-C.3		3	40-48	1	1	1	**3**	Hypersufilidic sand		

Table A-24. Summary of temporal changes in ASS Classification, acidification hazard [1](**H** = High; **M** = medium; **L** = Low; **VL** = Very Low), site condition and profile chemistry and morphology (Refer to previous two figures and table)

Sampling	[1]ASS Classification & [2]Acidification hazard	Site photographs	Notes
Drought End winter 2009 (a)	**Sulfuric* (H)**		During the extreme drought period (2007 to 2009) the drying of Loveday Bay caused Hypersulfidic subaqueous soil to transform to Sulfuric soil. Inundation, following winter 2010, caused the formation of Hypersulfidic subaqueous soil.
Drought End summer 2010 (b)	**Sulfuric (H)**		
Post-drought Summer 2011 (c)	**Hypersulfidic subaqueous (M)**		
Post-drought Winter 2011 (d)	**Hypersulfidic subaqueous (H)**		
Post-drought Start summer 2011/12 (e)	**Hypersulfidic subaqueous (M)**		
Post-drought Start winter 2012 (f)	**Hypersulfidic subaqueous (M)**		
Post-drought Summer 2013 (g)	**Hypersulfidic subaqueous (M)**		

A.10 LF13: Tauwitcherie

LF13-A

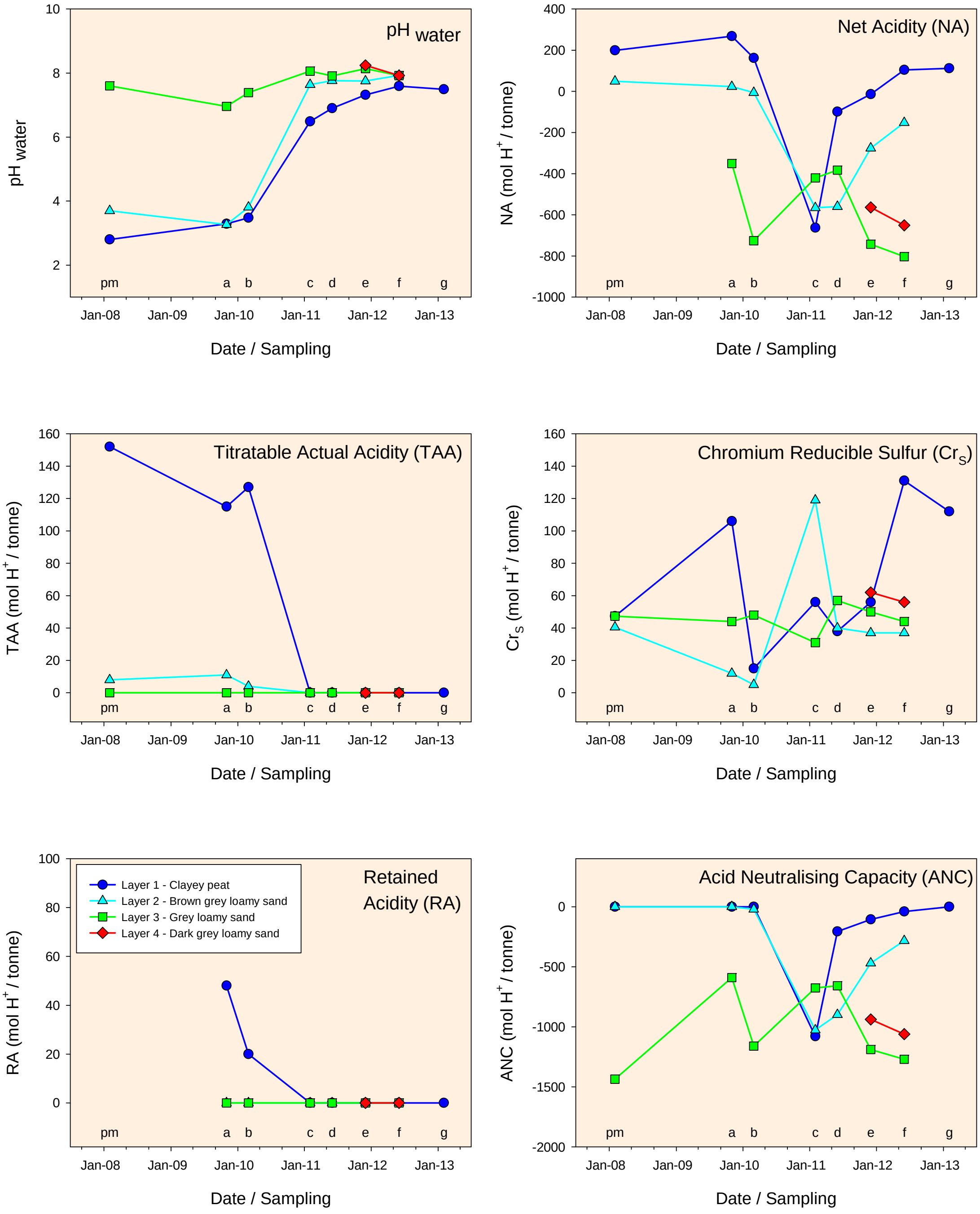


Figure A-25. Plots describing the location and quantity of acidity and acid neutralisation capacity within the soil profile and how this alters through time in response to drought and subsequent reflooding

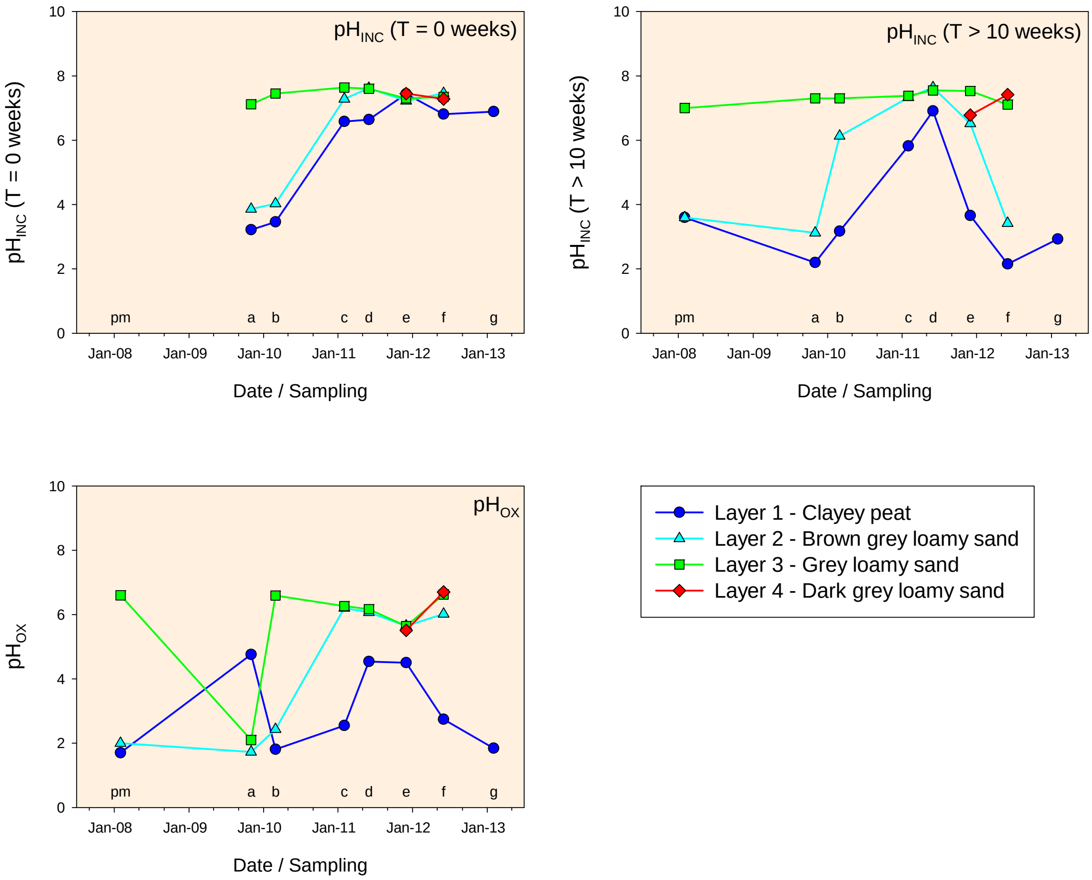


Figure A-26. Plots describing the acidification potential of soil material from different depths in the soil profile through time

Table A-25 Summary of acidification potential, ASS material classification, ASS subtype classification and acidification hazard (* indicates sulfuric soil material). The soil texture in brackets following the ASS subtype classification indicates the dominant texture of the profile. The layer number refers to soil layers and corresponding data that are plotted in the previous two figures. NC: non-continuous soil layers that were not encountered during the majority of samplings

Sample	Sampling	Layer	Depth (cm)	pH$_{OX}$ < 2.5	pH$_{INC}$ < 4.0	NA > 0	Acidification potential	ASS material classification	ASS subtype	Acidification hazard
LF13-A										
AA 33.2	pm	1	1-10	1	1	1	**3***	Sulfuric peat	Sulfuric clay soil (sand)	**High**
AA33.3		NC	10-25	1	1	1	**3***	Sulfuric clay		
AA 33.4		2	25-40	1	1	1	**3***	Sulfuric sand		
AA 33.5		3	40-60	0	0	0	0	Hyposulfidic sand		
LFa13-A.1	a	1	0-13	0	1	1	2*	Sulfuric silty clay	Sulfuric soil (sand)	**High**
LFa13-A.2		2	13-18	1	1	1	**3***	Sulfuric loamy sand		
LFa13-A.3		3	18-50	1	0	0	1	Hyposulfidic loamy sand		
LFb13-A.1	b	1	0-12	1	1	1	**3***	Sulfuric silty heavy clay	Sulfuric soil (sand)	**High**
LFb13-A.2		2	12-20	1	0	0	1*	Sulfuric loamy sand		
LFb13-A.3		3	20-50	0	0	0	0	Hyposulfidic loamy sand		
LFc13-A.1	c	1	0-10	0	0	0	0	Hyposulfidic fibric peat	Hyposulfidic subaqueous soil (sand)	**Low**
LFc13-A.2		2	10-35	0	0	0	0	Hyposulfidic silty sand		
LFc13-A.3		3	35-50	0	0	0	0	Hyposulfidic silty sand		
LFd13-A.1	d	1	0-12	0	0	0	0	Hyposulfidic peaty sand	Hyposulfidic subaqueous soil (sand)	**Low**
LFd13-A.2		2	12-36	0	0	0	0	Hyposulfidic loamy sand		
LFd13-A.3		3	36-50	0	0	0	0	Hyposulfidic sandy loam		
LFe13-A.2	e	1	0-13	0	1	0	1	Hypersufilidic fibric peat	Hyposulfidic subaqueous soil (sand)	**Low**
LFe13-A.3		2	13-31	0	0	0	0	Hyposulfidic loamy sand		
LFe13-A.4		3	31-47	0	0	0	0	Hyposulfidic loamy sand		
LFe13-A.5		4	47-65	0	0	0	0	Hyposulfidic sandy clay loam		
LFf13-A.1	f	1	0-12	0	1	1	2	Hypersufilidic fibric peat	Hypersulfidic subaqueous organic soil (sand)	**Low**
LFf13-A.2		2	12-22	0	1	0	1	Hypersufilidic loamy sand		
LFf13-A.3		3	22-40	0	0	0	0	Hyposulfidic loamy sand		
LFf13-A.4		4	40-50	0	0	0	0	Hyposulfidic loamy sand		
LFg13-A.1	g	1	0-14	1	1	1	**3**	Hypersufilidic fibric peat	Hypersulfidic subaqueous organic soil (sand)	**Low**
LFg13-A.2		NC	14-44	0	0	0	0	Hyposulfidic loamy sand		

Table A-26. Summary of temporal changes in ASS Classification, acidification hazard [1](**H** = High; **M** = medium; **L** = Low; **VL** = Very Low), site condition and profile chemistry and morphology (Refer to previous two figures and table)

Sampling	[1]ASS Classification & [2]Acidification hazard	Site photographs	Notes
Pre-monitoring Drought Summer 2008 (pm)	**Sulfuric clay (H)**		During the extreme drought period (2007 to 2009) soil remained Sulfuric. Inundation, following winter 2010, caused the formation of Hypersulfidic and Hyposulfidic subaqueous soil.
Drought End winter 2009 (a)	**Sulfuric* (H)**		
Drought End summer 2010 (b)	**Sulfuric* (H)**		
Post-drought Summer 2011 (c)	**Hyposulfidic subaqueous (L)**		
Post-drought Winter 2011 (d)	**Hyposulfidic subaqueous (L)**		
Post-drought Start summer 2011/12 (e)	**Hyposulfidic subaqueous (L)**		
Post-drought Start winter 2012 (f)	**Hypersulfidic subaqueous (L)**		
Post-drought Summer 2013 (g)	**Hypersulfidic subaqueous (L)**		

A.11 LF15: Boggy Creek

LF15-B

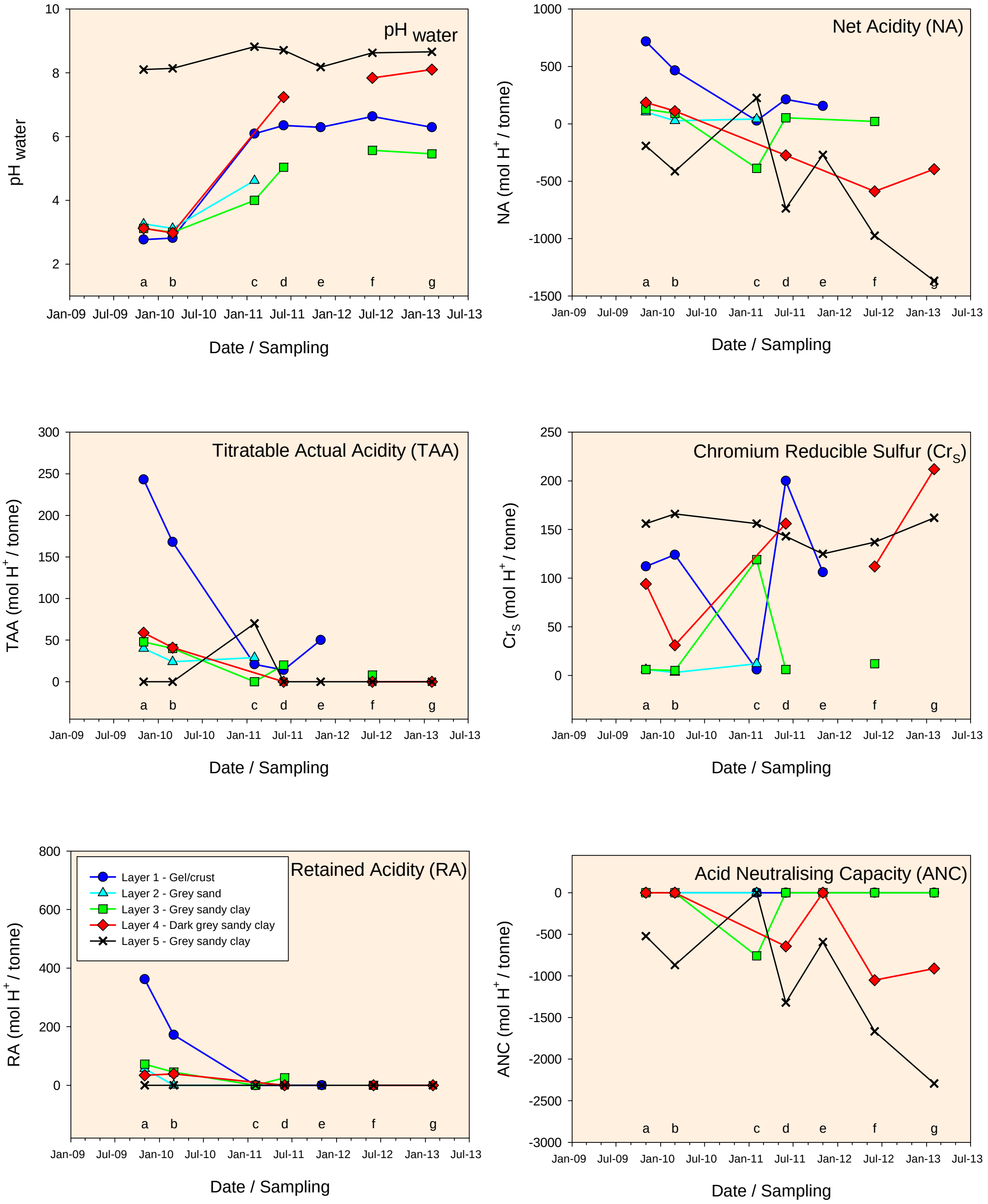


Figure A-27. Plots describing the location and quantity of acidity and acid neutralisation capacity within the soil profile and how this alters through time in response to drought and subsequent reflooding

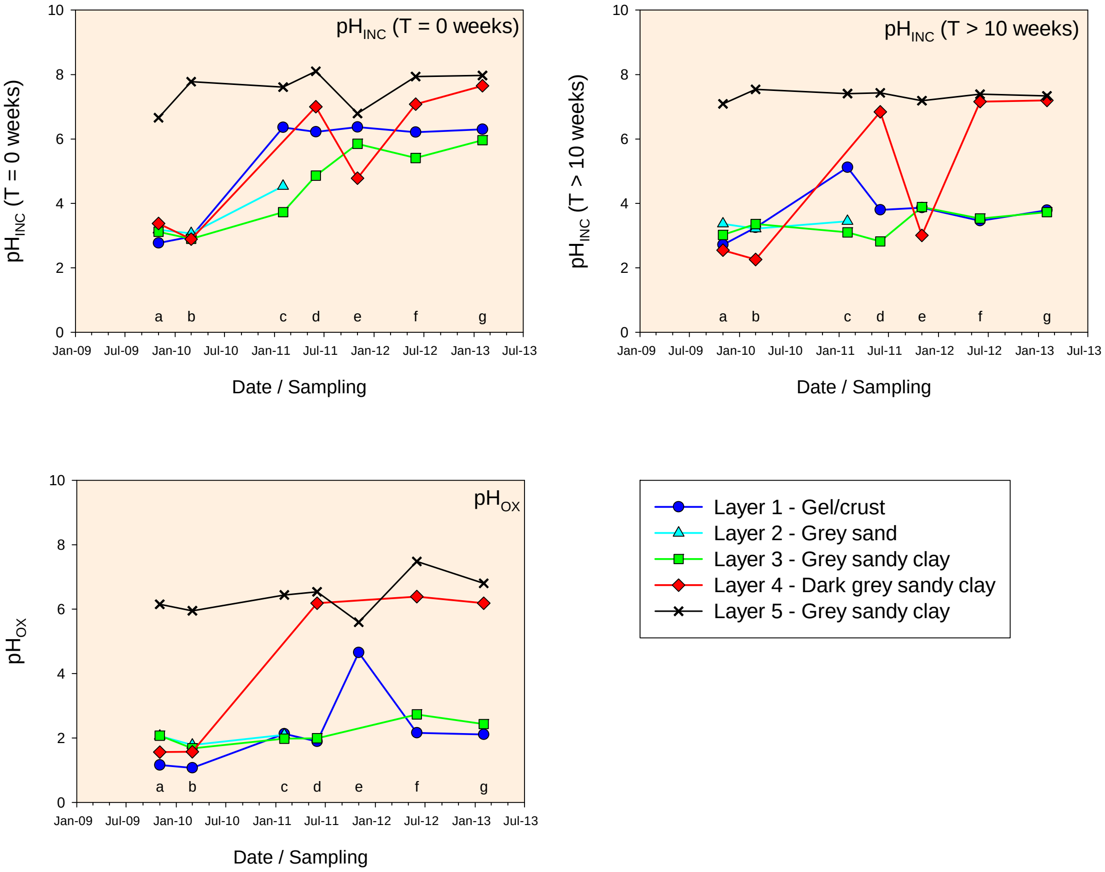


Figure A-28. Plots describing the acidification potential of soil material from different depths in the soil profile through time

Table A-27 Summary of acidification potential, ASS material classification, ASS subtype classification and acidification hazard (* indicates sulfuric soil material). The soil texture in brackets following the ASS subtype classification indicates the dominant texture of the profile. The layer number refers to soil layers and corresponding data that are plotted in the previous two figures. NC: non-continuous soil layers that were not encountered during the majority of samplings

Sample	**Sampling**	**Layer**	**Depth (cm)**	**pH$_{OX}$ < 2.5**	**pH$_{INC}$ < 4.0**	**NA > 0**	**Acidification potential**	**ASS material classification**	**ASS subtype**	**Acidification hazard**
LF15-B										
LFa15-B.1	a	1	0-5	1	1	1	**3***	Sulfuric sandy clay	Sulfuric clay soil (clay)	**High**
LFa15-B.2		2	5-20	1	1	1	**3***	Sulfuric sandy clay		
LFa15-B.3		3	20-25	1	1	1	**3***	Sulfuric sandy clay		
LFa15-B.4		4	25-35	1	1	1	**3***	Sulfuric sandy clay		
LFa15-B.5		5	35-70	0	0	0	0	Hyposulfidic clayey sand		
LFb15-B.1	b	1	0-5	1	1	1	**3***	Sulfuric loam	Sulfuric clay soil (clay)	**High**
LFb15-B.2		2	5-15	1	1	1	**3***	Sulfuric sand		
LFb15-B.3		3	15-20	1	1	1	**3***	Sulfuric sandy clay		
LFb15-B.4		4	20-30	1	1	1	**3***	Sulfuric sandy clay		
LFb15-B.5		NC	30-45	1	1	1	**3***	Sulfuric sandy loam		
LFb15-B.6		5	45-70	0	0	0	0	Hyposulfidic sandy clay		
LFc15-B.1	c	1	0-6	1	0	1	2	Hyposulfidic sand	Hypersulfidic subaqueous clay soil (clay)	**High**
LFc15-B.2		2	6-12	1	1	1	**3**	Hypersulfidic sand		
LFc15-B.3		3	12-24	1	1	0	2	Hypersulfidic sandy clay		
LFc15-B.4		NC	24-60	0	0	0	0	Hyposulfidic sandy loam		
LFc15-B.5		5	60-80	0	0	1	1	Hyposulfidic sandy clay		
LFd15-B.1	d	1	0-6	1	1	1	**3**	Hypersulfidic sandy gel	Hypersulfidic subaqueous clay soil (clay)	**High**
LFd15-B.2		3	6-12	1	1	1	**3**	Hypersulfidic loamy sand		
LFd15-B.3		NC	12-24	1	1	1	**3**	Hypersulfidic sandy loam		
LFd15-B.4		4	24-60	0	0	0	0	Hyposulfidic sandy clay		
LFd15-B.5		5	60-80	0	0	0	0	Hyposulfidic sandy clay		
LFe15-B.1	e	1	0-7	0	1	1	2	Hypersufilidic gel	Hypersulfidic subaqueous clay soil (clay)	**Medium**
LFe15-B.3		3	14-32	0	1	1	2	Hypersufilidic sandy loam		
LFe15-B.5		NC	39-60	0	0	0	0	Hyposulfidic sandy loam		
LFe15-B.6		NC	60-84	0	0	0	0	Hyposulfidic sandy		
LFf15-B.2	f	3	2-12	0	1	1	2	Hypersufilidic loamy sand	Hypersulfidic subaqueous soil (clay)	**Medium**
LFf15-B.3		NC	12-27	0	1	1	2	Hypersufilidic sandy loam		
LFf15-B.4		4	27-54	0	0	0	0	Hyposulfidic sandy clay		
LFf15-B.5		5	54-82	0	0	0	0	Hyposulfidic sandy clay		
LFg15-B.3	g	NC	13-27	1	1	1	**3**	Hypersufilidic sandy loam	Hypersulfidic subaqueous soil (sand)	**Medium**
LFg15-B.4		4	27-47	0	0	0	0	Hyposulfidic clayey sand		
LFg15-B.5		5	47-62	0	0	0	0	Hyposulfidic clayey coarse sand		

Table A-28. Summary of temporal changes in ASS Classification, acidification hazard [1](**H** = High; **M** = medium; **L** = Low; **VL** = Very Low), site condition and profile chemistry and morphology (Refer to previous two figures and table)

Sampling	**[1]ASS Classification & [2]Acidification hazard**	**Site photographs**	**Notes**
Drought End winter 2009 (a)	**Sulfuric* clay (H)**		During the extreme drought period (2007 to 2009) soil remained Sulfuric. Inundation, following winter 2010, encouraged sulfate reduction and caused the formation of Hypersulfidic subaqueous clays.
Drought End summer 2010 (b)	**Sulfuric* clay (H)**		
Post-drought Summer 2011 (c)	**Hypersulfidic subaqueous clay (H)**		
Post-drought Winter 2011 (d)	**Hypersulfidic subaqueous clay (H)**		
Post-drought Start summer 2011/12 (e)	**Hypersulfidic subaqueous clay (M)**		
Post-drought Start winter 2012 (f)	**Hypersulfidic subaqueous clay (M)**		
Post-drought Summer 2013 (g)	**Hypersulfidic subaqueous clay (M)**		

A.12 LF17: Point Sturt South

LF17-A

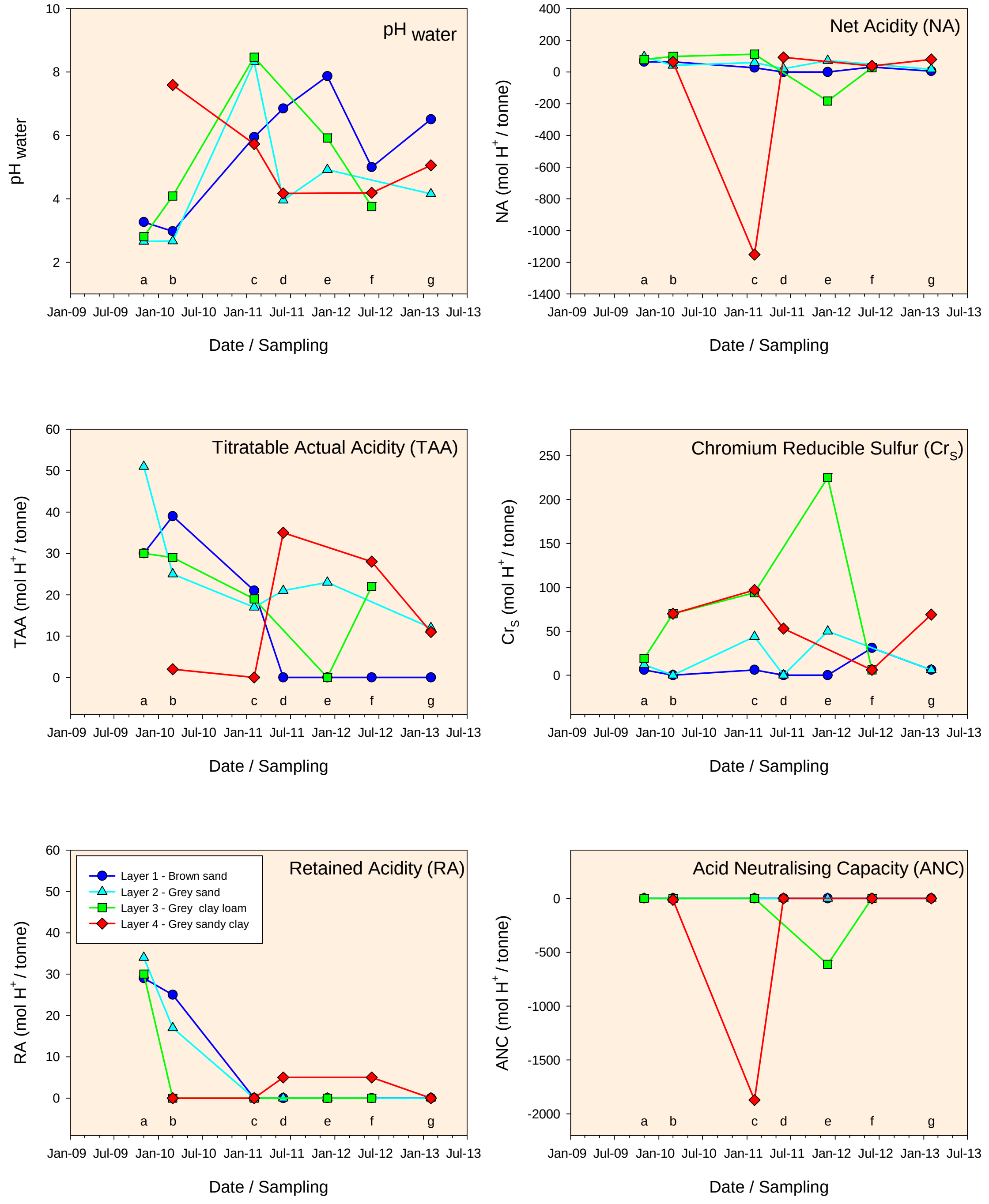


Figure A-29. Plots describing the location and quantity of acidity and acid neutralisation capacity within the soil profile and how this alters through time in response to drought and subsequent reflooding

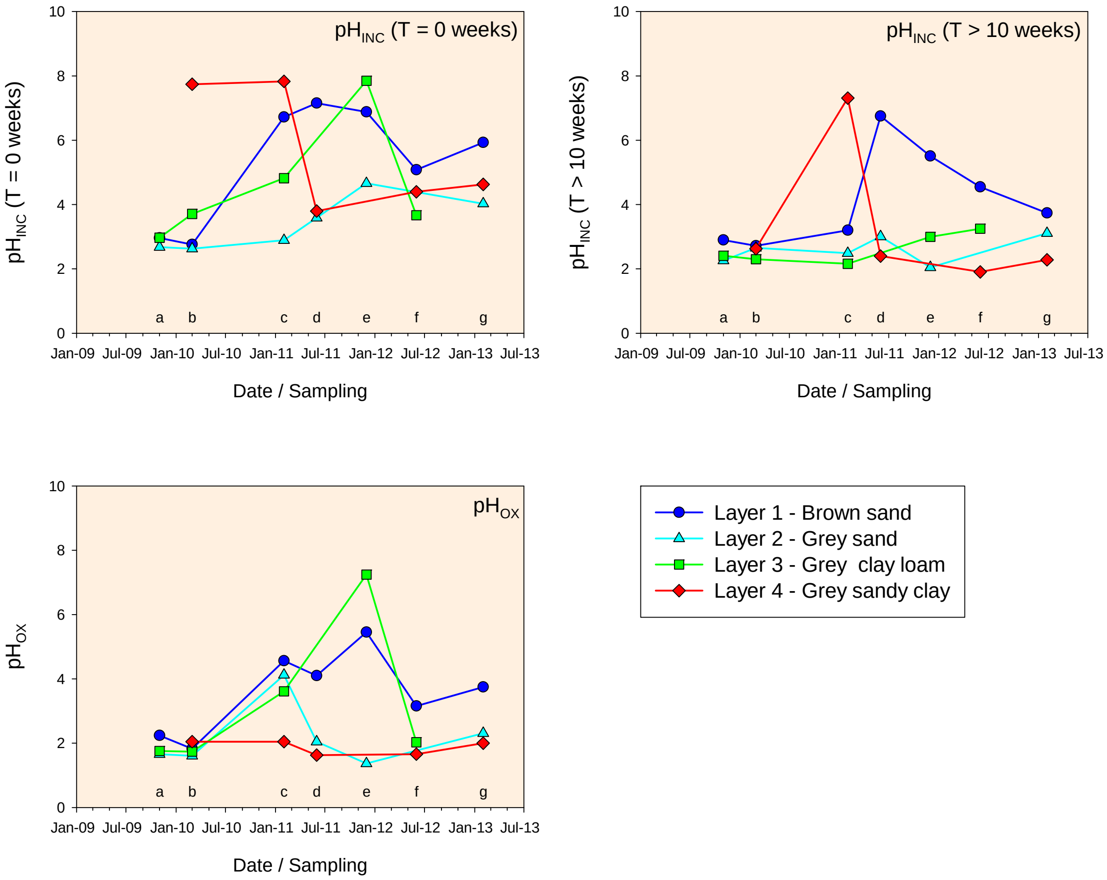
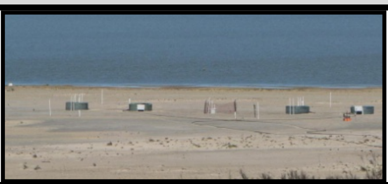


Figure A-30. Plots describing the acidification potential of soil material from different depths in the soil profile through time

Table A-29 Summary of acidification potential, ASS material classification, ASS subtype classification and acidification hazard (* indicates sulfuric soil material). The soil texture in brackets following the ASS subtype classification indicates the dominant texture of the profile. The layer number refers to soil layers and corresponding data that are plotted in the previous two figures. NC: non-continuous soil layers that were not encountered during the majority of samplings

Sample	Sampling	Layer	Depth (cm)	pH_{OX} < 2.5	pH_{INC} < 4.0	NA > 0	Acidification potential	ASS material classification	ASS subtype	Acidification hazard
LF17-A										
LFa17-A.1	a	1	0-15	1	1	1	**3***	Sulfuric sand	Sulfuric soil (sand)	**High**
LFa17-A.2		2	15-30	1	1	1	**3***	Sulfuric sandy clay		
LFa17-A.3		3	30-45	1	1	1	**3***	Sulfuric sand		
LFa17-A.4		NC	45-60	1	1	1	**3**	Hypersulfidic sand		
LFb17-A.1	b	NC	0-2	1	1	1	**3***	Sulfuric sand	Sulfuric soil (sand)	**High**
LFb17-A.2		1	2-20	1	1	1	**3***	Sulfuric sand		
LFb17-A.3		2	30-38	1	1	1	**3***	Sulfuric sand		
LFb17-A.4		3	38-58	1	1	1	**3**	Hypersulfidic clay loam		
LFb17-A.5		4	58-68	1	1	1	**3**	Hypersulfidic sandy clay loam		
LFc17-A.2	c	1	2-30	0	1	1	2	Hypersulfidic sand	Hypersulfidic subaqueous soil (sand)	**Medium**
LFc17-A.3		2	30-40	0	1	1	2	Hypersulfidic sand		
LFc17-A.4		3	40-53	0	1	1	2	Hypersulfidic clayey loam		
LFc17-A.5		4	53-60	1	0	0	1	Hyposulfidic sandy clay loam		
LFd17-A.1	d	1	0-20	0	0	0	0	Sandy	Sulfuric subaqueous soil (sand)	**High**
LFd17-A.2		2	20-47	1	1	1	**3***	Sulfuric loamy sand		
LFd17-A.3		4	47-60	1	1	1	**3**	Hypersulfidic sandy clay loam		
LFd17-A.4		5	60-73	1	1	1	**3**	Hypersulfidic sandy loam		
LFe17-A.1	e	1	0-19	0	0	0	0	Loamy sand	Hypersulfidic subaqueous soil (sand)	**Medium**
LFe17-A.2		NC	19-49	0	1	1	2	Loamy sand		
LFe17-A.3		2	49-63	1	1	1	**3**	Hypersufilidic heavy clay		
LFe17-A.4		3	63-65	0	1	0	1	Hypersufilidic loamy sand		
LFe17-A.5		NC	65-70	0	0	1	1	Hyposulfidic sapric peat		
LFf17-A.1	f	1	0-17	0	0	1	1	Hyposulfidic loamy sand	Sulfuric subaqueous clay soil (clay)	**High**
LFf17-A.2		3	17-46	1	1	1	**3***	Sulfuric sandy clay		
LFf17-A.3		4	46-80	1	1	1	**3**	Hypersufilidic sandy clay		
LFg17-A.1	g	1	0-20	0	1	1	2	Hypersufilidic sand	Hypersulfidic subaqueous soil (sand)	**High**
LFg17-A.2		2	20-55	1	1	1	**3**	Hypersufilidic sand		
LFg17-A.3		4	55-75	1	1	1	**3**	Hypersufilidic clayey sand		

Table A-30. Summary of temporal changes in ASS Classification, acidification hazard [1](**H** = High; **M** = medium; **L** = Low; **VL** = Very Low), site condition and profile chemistry and morphology (Refer to previous two figures and table)

Sampling	**[1]ASS Classification & [2]Acidification hazard**	**Site photographs**	**Notes**
Drought End winter 2009 (a)	**Sulfuric* (H)**		During the extreme drought period (2007 to 2009) soil remained Sulfuric. Inundation, following winter 2010, caused the formation of Sulfuric and Hypersulfidic subaqueous soil.
Drought End summer 2010 (b)	**Sulfuric* (H)**		
Post-drought Summer 2011 (c)	**Hypersulfidic subaqueous (M)**		
Post-drought Winter 2011 (d)	**Sulfuric* subaqueous (H)**		
Post-drought Start summer 2011/12 (e)	**Hypersulfidic subaqueous (M)**		
Post-drought Start winter 2012 (f)	**Sulfuric* subaqueous (H)**		
Post-drought Summer 2013 (g)	**Hypersulfidic subaqueous (H)**		

LF17-B

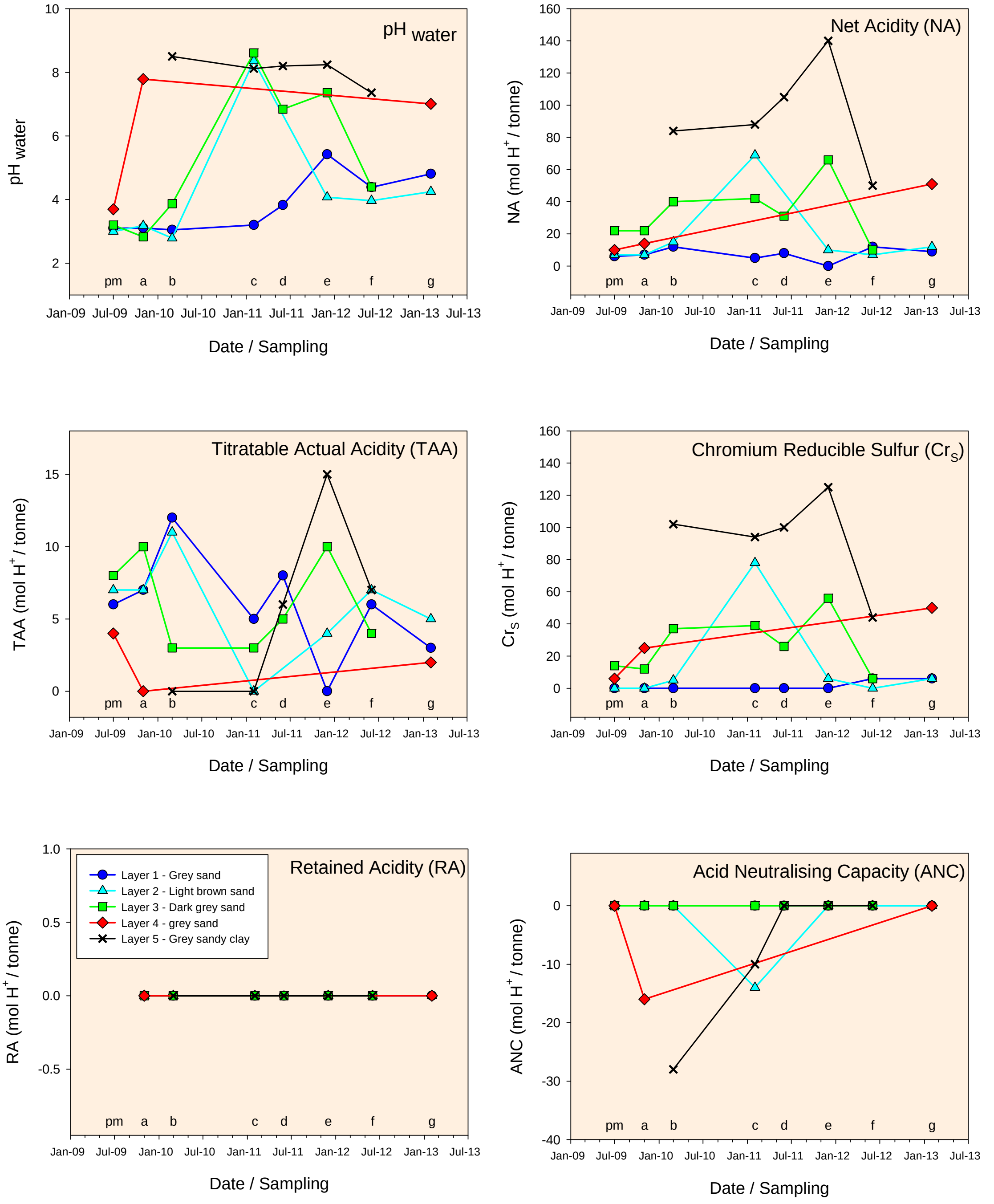


Figure A-31. Plots describing the location and quantity of acidity and acid neutralisation capacity within the soil profile and how this alters through time in response to drought and subsequent reflooding

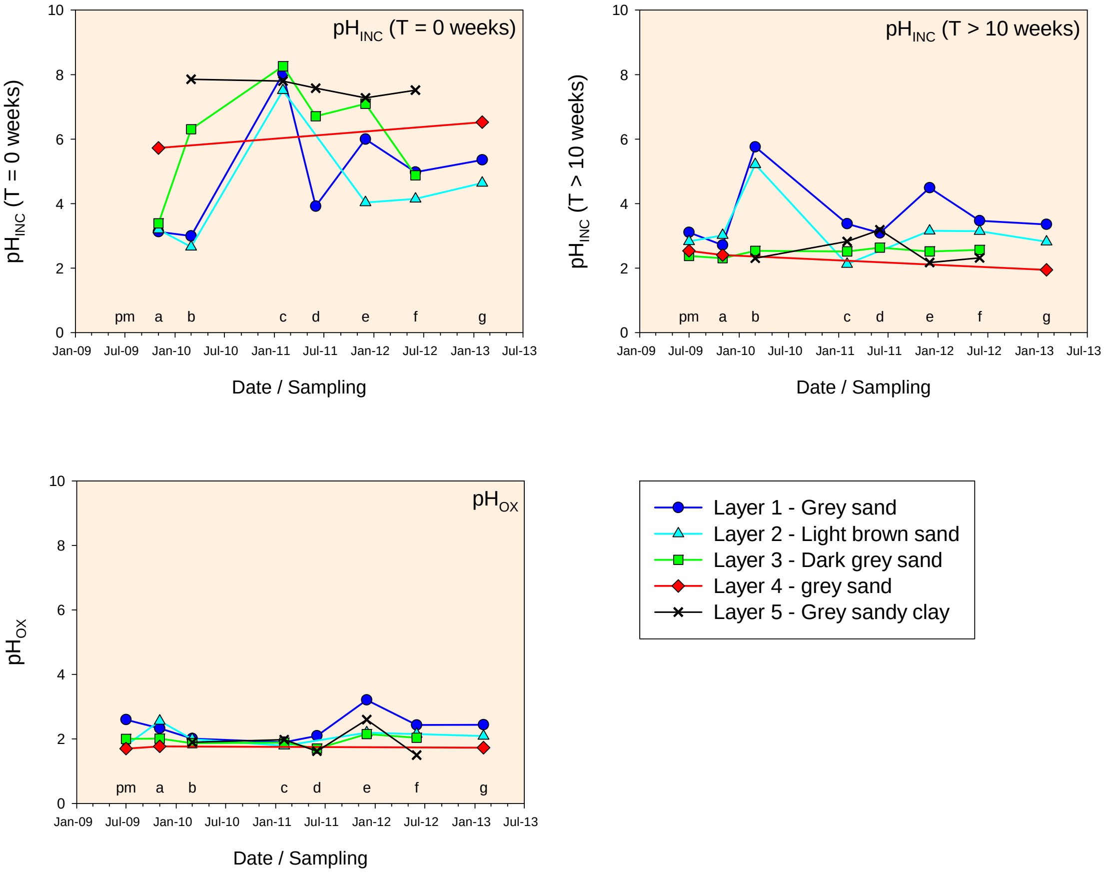


Figure A-32. Plots describing the acidification potential of soil material from different depths in the soil profile through time

Table A-31 Summary of acidification potential, ASS material classification, ASS subtype classification and acidification hazard (* indicates sulfuric soil material). The soil texture in brackets following the ASS subtype classification indicates the dominant texture of the profile. The layer number refers to soil layers and corresponding data that are plotted in the previous two figures. NC: non-continuous soil layers that were not encountered during the majority of samplings

Sample	**Sampling**	**Layer**	**Depth (cm)**	**pH_{OX} < 2.5**	**pH_{INC} < 4.0**	**NA > 0**	**Acidification potential**	**ASS material classification**	**ASS subtype**	**Acidification hazard**
LF17-B										
PSM 1.1	pm	NC	0-0.5	0	1	1	2*	Sulfuric crystals	Sulfuric soil (sand)	**High**
PSM 1.2		NC	0.5-1	1	1	1	**3***	Sulfuric crystals		
PSM 1.3		1	1-10	0	1	1	2*	Sulfuric sand		
PSM 1.4		NC	10-20	1	1	1	**3***	Sulfuric sand		
PSM 1.5		2	20-30	1	1	1	**3***	Sulfuric sand		
PSM 1.6		3	30-40	1	1	1	**3***	Sulfuric sand		
PSM 1.7		4	40-50	1	1	1	**3***	Sulfuric sand		
PSM 1.8		NC	50-60	1	1	1	**3**	Hypersulfidic sandy clay		
LFa17-B.1	a	1	0-15	1	1	1	**3***	Sulfuric sand	Sulfuric soil (sand)	**High**
LFa17-B.2		2	15-30	0	1	1	2*	Sulfuric sand		
LFa17-B.3		3	30-50	1	1	1	**3***	Sulfuric sand		
LFa17-B.4		4	50-70	1	1	1	**3**	Hypersulfidic sand		
LFb17-B.1	b	1	0-20	1	0	1	2*	Sulfuric sand	Sulfuric soil (sand)	**High**
LFb17-B.2		2	20-40	1	0	1	2*	Sulfuric sand		
LFb17-B.3		3	40-68	1	1	1	**3***	Sulfuric sand		
LFb17-B.4		5	68-90	1	1	1	**3**	Hypersulfidic sand		
LFc17-B.1	c	1	0-25	1	1	1	**3**	Sand	Hypersulfidic subaqueous soil (sand)	**High**
LFc17-B.2		2	25-38	1	1	1	**3**	Hypersulfidic sand		
LFc17-B.3		3	38-50	1	1	1	**3**	Hypersulfidic sand		
LFc17-B.4		5	50-68	1	1	1	**3**	Hypersulfidic clayey sand		
LFd17-B.1	d	NC	0-7	1	1	1	**3**	Sand	Sulfuric subaqueous soil (sand)	**High**
LFd17-B.2		1	7-25	1	1	1	**3***	Sulfuric sand		
LFd17-B.3		3	25-52	1	1	1	**3**	Hypersulfidic loamy sand		
LFd17-B.4		5	52-72	1	1	1	**3**	Hypersulfidic sandy clay loam		
LFe17-B.1	e	1	0-6	0	0	0	0	Sand	Hypersulfidic subaqueous soil (sand)	**High**
LFe17-B.2		2	6-25	1	1	1	**3**	Hypersufilidic sand		
LFe17-B.3		3	25-56	1	1	1	**3**	Hypersufilidic sand		
LFe17-B.4		5	56-77	0	1	1	2	Hypersufilidic clayey sand		
LFf17-B.1	f	1	0-23	1	1	1	**3**	Hypersufilidic loamy sand	Sulfuric subaqueous soil (sand)	**High**
LFf17-B.2		2	23-44	1	1	1	**3***	Sulfuric loamy sand		
LFf17-B.3		3	44-57	1	1	1	**3**	Hypersufilidic loamy sand		
LFf17-B.4		5	57-89	1	1	1	**3**	Hypersufilidic sandy clay loam		
LFg17-B.1	g	1	0-12	1	1	1	**3**	Hypersufilidic silty sand	Hypersulfidic subaqueous soil (sand)	**High**
LFg17-B.2		2	12-57	1	1	1	**3**	Hypersufilidic silty sand		
LFg17-B.3		4	57-77	1	1	1	**3**	Hypersufilidic silty sand		

Table A-32. Summary of temporal changes in ASS Classification, acidification hazard [1](**H** = High; **M** = medium; **L** = Low; **VL** = Very Low), site condition and profile chemistry and morphology (Refer to previous two figures and table)

Sampling	[1]ASS Classification & [2]Acidification hazard	Site photographs	Notes
Pre-monitoring **Drought** **Winter** **2009 (pm)**	**Sulfuric (H)**		During the extreme drought period (2007 to 2009) soil remained Sulfuric. Inundation, following winter 2010, caused the formation of Sulfuric and Hypersulfidic subaqueous soil.
Drought **End winter** **2009 (a)**	**Sulfuric (H)**		
Drought **End summer** **2010 (b)**	**Sulfuric (H)**		
Post-drought **Summer** **2011 (c)**	**Hypersulfidic subaqueous (H)**		
Post-drought **Winter** **2011 (d)**	**Hypersulfidic subaqueous (H)**		
Post-drought **Start summer** **2011/12 (e)**	**Hypersulfidic subaqueous (H)**		
Post-drought **Start winter** **2012 (f)**	**Sulfuric subaqueous (H)**		
Post-drought **Summer** **2013 (g)**	**Hypersulfidic subaqueous (H)**		

A.13 LF19: Dog Lake

LF19-A

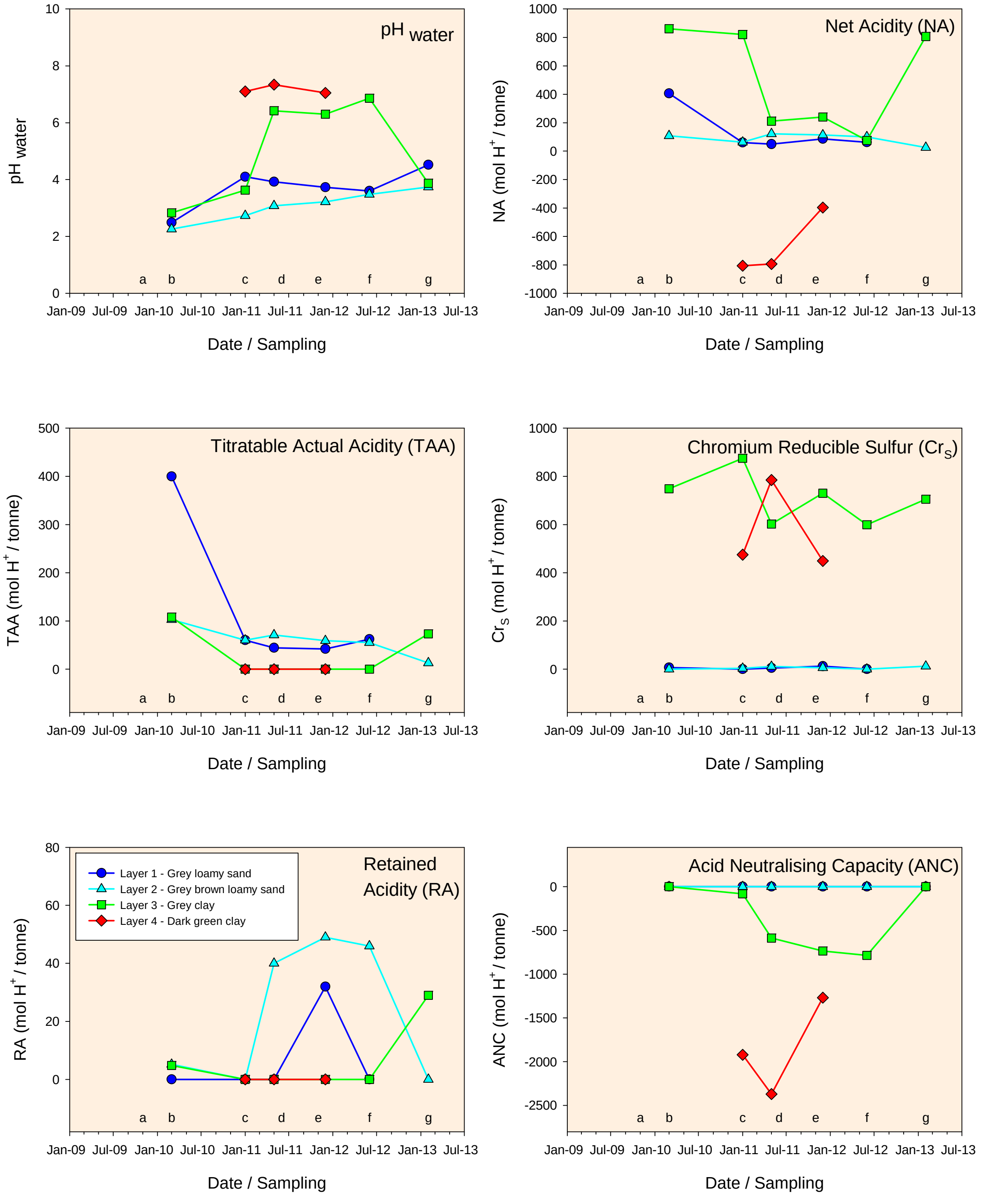


Figure A-33. Plots describing the location and quantity of acidity and acid neutralisation capacity within the soil profile and how this alters through time in response to drought and subsequent reflooding

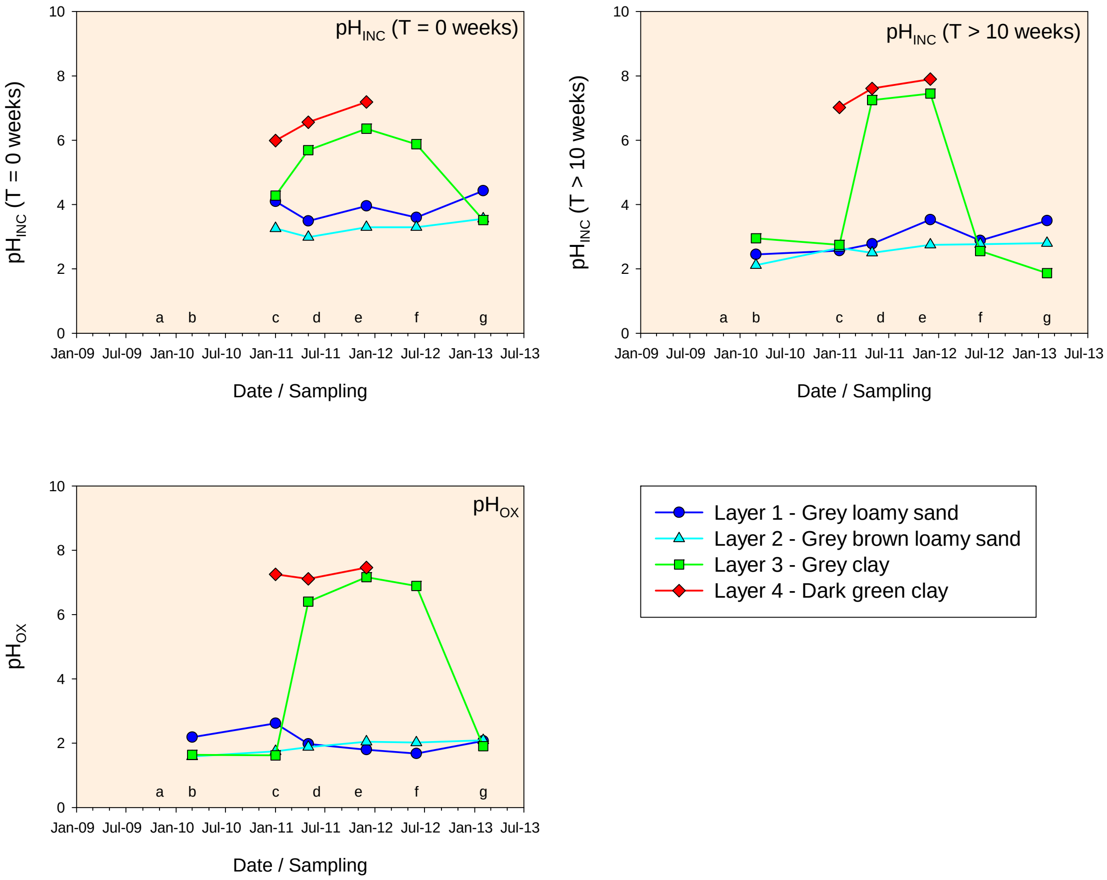


Figure A-34. Plots describing the acidification potential of soil material from different depths in the soil profile through time

Table A-33 Summary of acidification potential, ASS material classification, ASS subtype classification and acidification hazard (* indicates sulfuric soil material). The soil texture in brackets following the ASS subtype classification indicates the dominant texture of the profile. The layer number refers to soil layers and corresponding data that are plotted in the previous two figures. NC: non-continuous soil layers that were not encountered during the majority of samplings

Sample	Sampling	Layer	Depth (cm)	pH$_{OX}$ < 2.5	pH$_{INC}$ < 4.0	NA > 0	Acidification potential	ASS material classification	ASS subtype	Acidification hazard
LF19-A										
LFb19 A.1	b	1	0-0.5	1	1	1	3*	Sulfuric loamy sand	Sulfuric clay soil (clay)	High
LFb19 A.2		NC	0.5-5	1	1	1	3*	Sulfuric loamy sand		
LFb19 A.3		2	5-50	1	1	1	3*	Sulfuric clay		
LFb19 A.4		3	50-80	1	1	1	3*	Sulfuric clay		
LFc19-A.1	c	1	0-12	0	1	1	2	Loamy sand	Sulfuric subaqueous clay soil (clay)	High
LFc19-A.2		2	12-24	1	1	1	3*	Sulfuric loamy sand		
LFc19-A.3		3	24-43	1	1	1	3*	Sulfuric clay		
LFc19-A.4		4	43-50	0	0	0	0	Hyposulfidic clay		
LFd19-A.1	d	1	0-19	1	1	1	3*	Sulfuric loamy sand	Sulfuric subaqueous soil (sand)	High
LFd19-A.2		2	19-29	1	1	1	3*	Sulfuric clayey sand		
LFd19-A.3		3	29-45	0	0	1	1	Hyposulfidic sandy clay		
LFd19-A.4		4	43-58	0	0	0	0	Hyposulfidic clay		
LFe19-A.1	e	1	0-16	1	1	1	3*	Sulfuric loamy sand	Sulfuric subaqueous soil (clay)	High
LFe19-A.2		2	16-24	1	1	1	3*	Sulfuric loamy sand		
LFe19-A.3		3	24-46	0	0	1	1	Hyposulfidic loamy clay		
LFe19-A.4		4	46-53	0	0	0	0	Hyposulfidic heavy clay		
LFf19-A.1	f	1	0-18	1	1	1	3*	Sulfuric loamy sand	Sulfuric subaqueous soil (sand)	High
LFf19-A.2		2	18-32	1	1	1	3*	Sulfuric clayey sand		
LFf19-A.3		3	32-42	0	1	1	2	Hypersufilidic light clay		
LFg19-A.2	g	2	5-30	1	1	1	3*	Sulfuric silty sand	Sulfuric subaqueous soil (sand)	High
LFg19-A.3		3	30-42	1	1	1	3*	Sulfuric silty sandy clay		

Table A-34. Summary of temporal changes in ASS Classification, acidification hazard [1](**H** = High; **M** = medium; **L** = Low; **VL** = Very Low), site condition and profile chemistry and morphology (Refer to previous two figures and table)

Sampling	[1]**ASS Classification & [2]Acidification hazard**	**Site photographs**	**Notes**
Drought End summer 2010 (b)	**Sulfuric* clay (H)**		During the extreme drought period (2007 to 2009) soil remained Sulfuric. Inundation, following winter 2010, caused the formation of Sulfuric subaqueous soil.
Post-drought Summer 2011 (c)	**Sulfuric subaqueous clay (H)**		
Post-drought Winter 2011 (d)	**Sulfuric* subaqueous (H)**		
Post-drought Start summer 2011/12 (e)	**Sulfuric* subaqueous (H)**		
Post-drought Start winter 2012 (f)	**Sulfuric* subaqueous (H)**		
Post-drought Summer 2013 (g)	**Sulfuric* subaqueous (H)**		

LF19-B

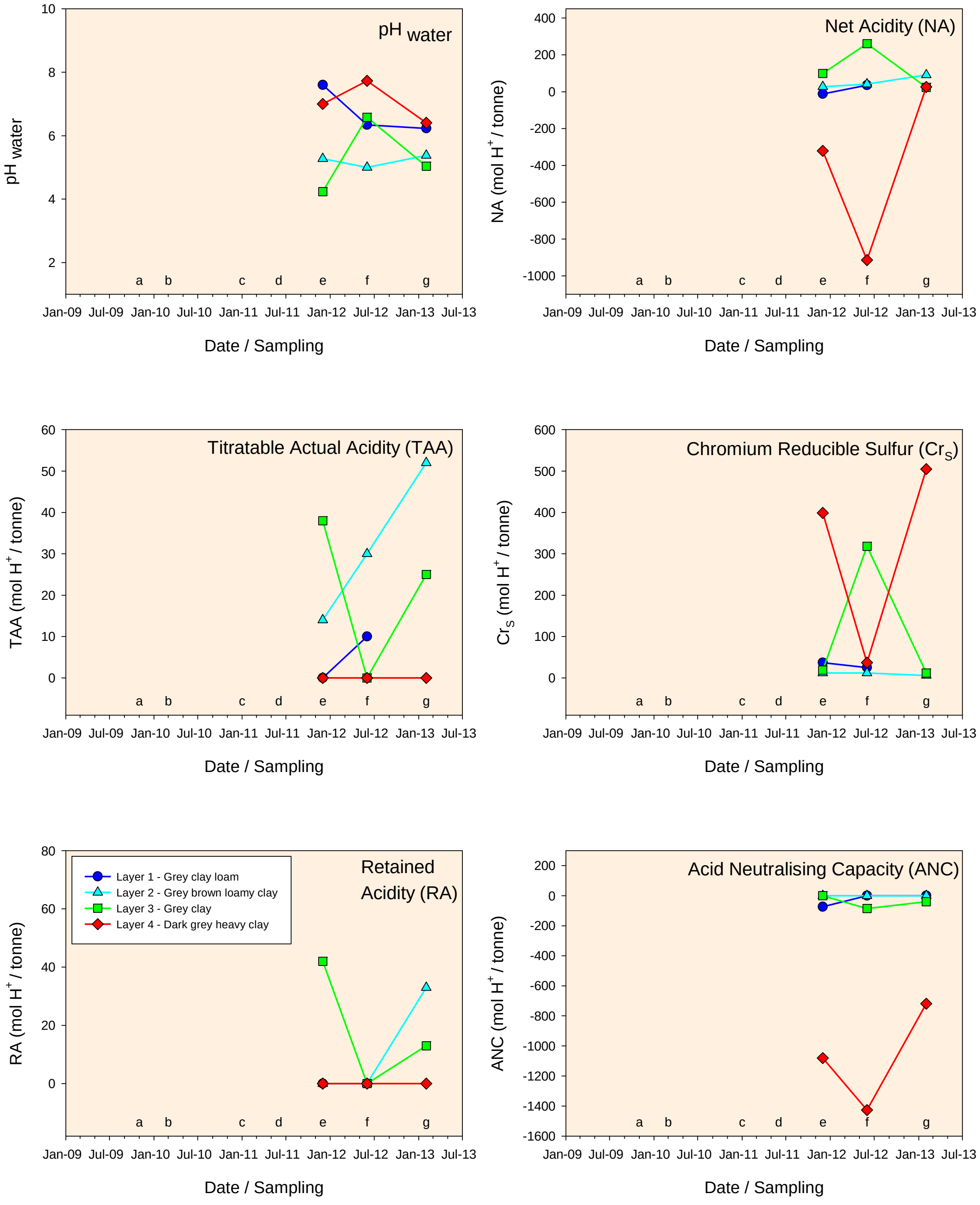


Figure A-35. Plots describing the location and quantity of acidity and acid neutralisation capacity within the soil profile and how this alters through time in response to drought and subsequent reflooding

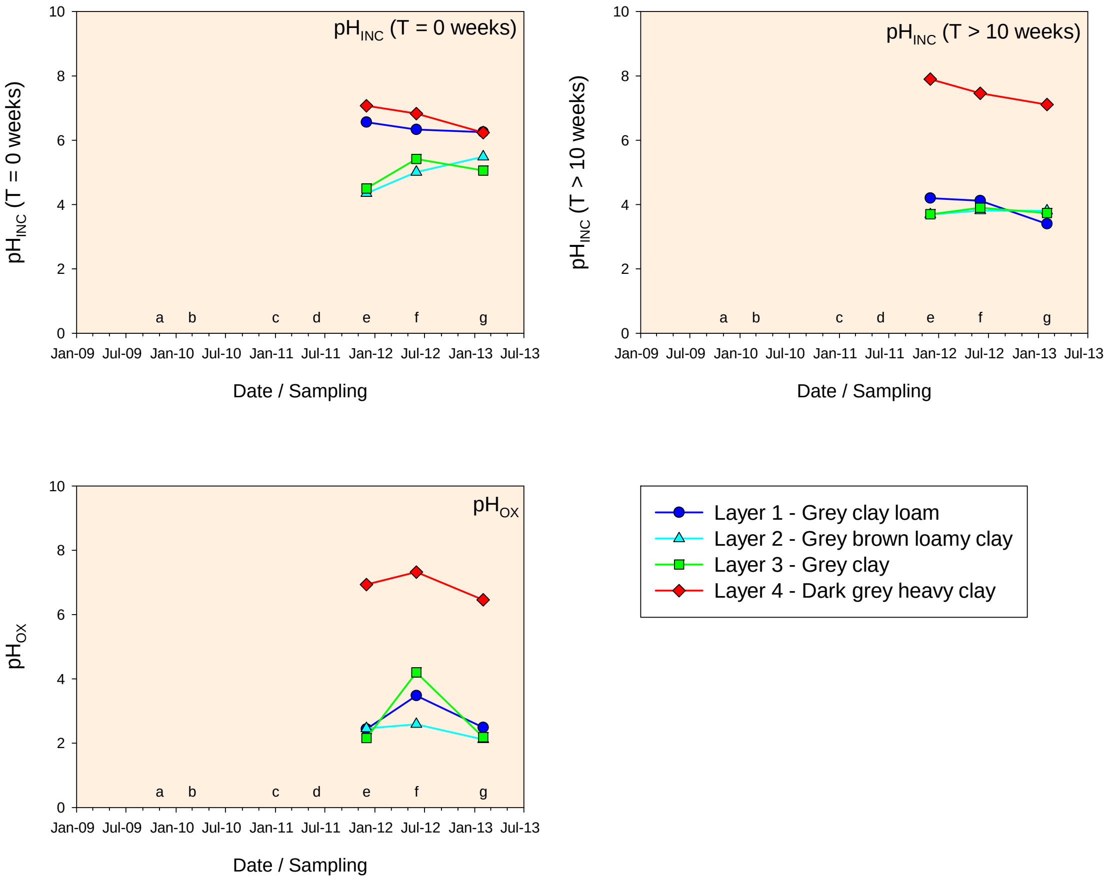


Figure A-36. Plots describing the acidification potential of soil material from different depths in the soil profile through time

Table A-35 Summary of acidification potential, ASS material classification, ASS subtype classification and acidification hazard (* indicates sulfuric soil material). The soil texture in brackets following the ASS subtype classification indicates the dominant texture of the profile. The layer number refers to soil layers and corresponding data that are plotted in the previous two figures. NC: non-continuous soil layers that were not encountered during the majority of samplings

Sample	Sampling	Layer	Depth (cm)	pH$_{OX}$ < 2.5	pH$_{INC}$ < 4.0	NA > 0	Acidification potential	ASS material classification	ASS subtype	Acidification hazard
LF19-B										
LFe19-B.1	e	1	0-13	1	0	0	1	Hyposulfidic medium clay	Hypersulfidic subaqueous clay soil (clay)	**Medium**
LFe19-B.2		2	13-27	1	1	1	**3**	Hypersufilidic loamy clay		
LFe19-B.3		3	27-45	1	1	1	**3**	Hypersufilidic loamy clay		
LFe19-B.4		4	45-56	0	0	0	0	Hyposulfidic heavy clay		
LFf19-B.1	f	1	0-8	0	0	1	1	Hyposulfidic clay loam	Hypersulfidic subaqueous clay soil (clay)	**Medium**
LFf19-B.2		2	8-26	0	1	1	2	Hypersufilidic light clay		
LFf19-B.3		3	26-36	0	1	1	2	Hypersufilidic light clay		
LFf19-B.4		4	36-49	0	0	0	0	Hyposulfidic heavy clay		
LFg19-B.2	g	2	6-26	1	1	1	**3**	Hypersufilidic sandy clay	Hypersulfidic subaqueous clay soil (clay)	**Medium**
LFg19-B.3		3	26-41	1	1	1	**3**	Hypersufilidic clay		
LFg19-B.4		4	41-51	0	0	1	1	Hyposulfidic silty clay		

Table A-36. Summary of temporal changes in ASS Classification, acidification hazard [1](**H** = High; **M** = medium; **L** = Low; **VL** = Very Low), site condition and profile chemistry and morphology (Refer to previous two figures and table)

Sampling	[1]ASS Classification & [2]Acidification hazard	Site photographs	Notes
Post-drought Start summer 2011/12 (e)	**Hypersulfidic subaqueous clay (M)**		Following inundation in winter 2010, soil material remained Hypersulfidic subaqueous clay soil.
Post-drought Start winter 2012 (f)	**Hypersulfidic subaqueous clay (M)**		
Post-drought Summer 2013 (g)	**Hypersulfidic subaqueous clay (M)**		

A.14 LF20: Boggy Lake

LF20-A

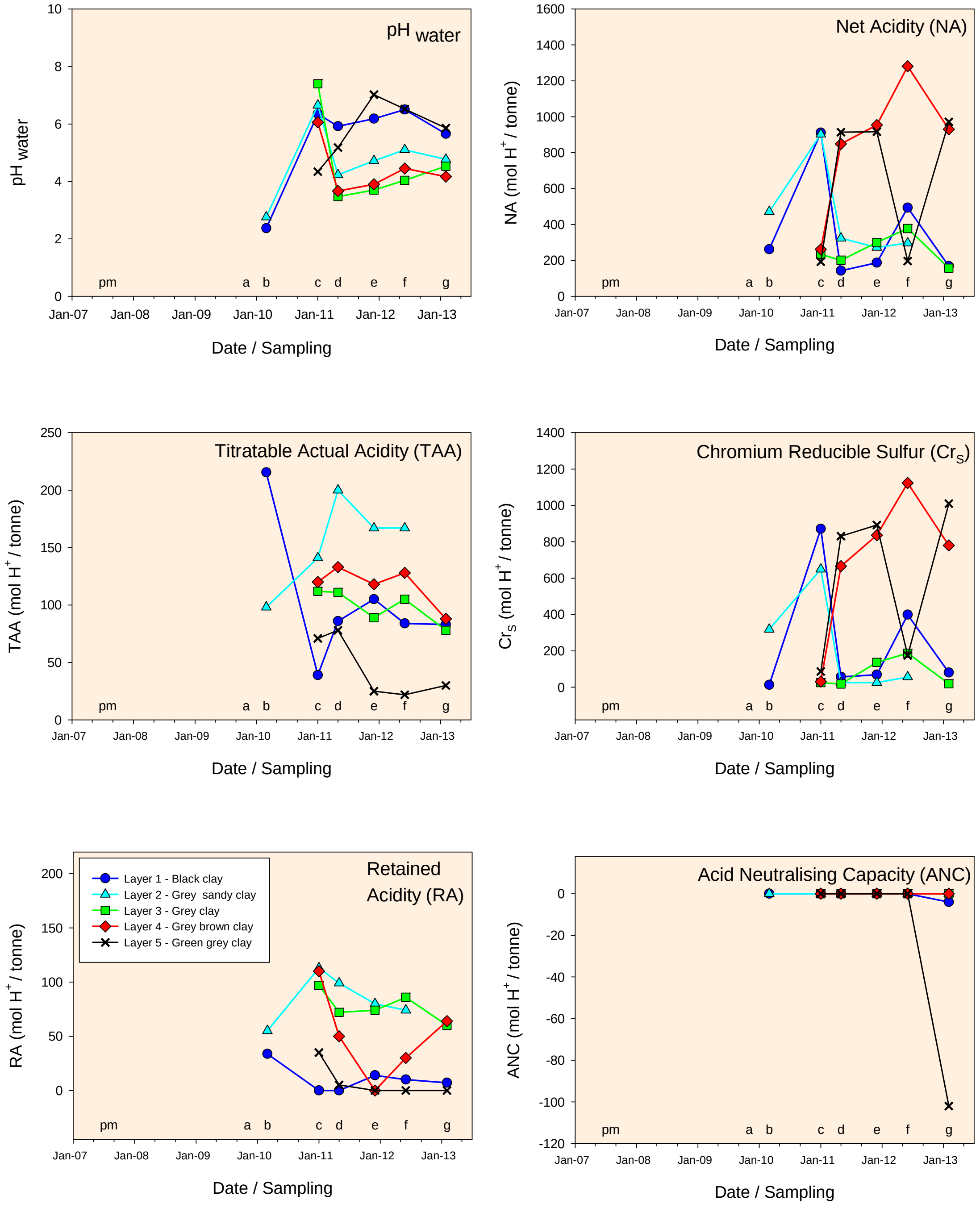


Figure A-37. Plots describing the location and quantity of acidity and acid neutralisation capacity within the soil profile and how this alters through time in response to drought and subsequent reflooding

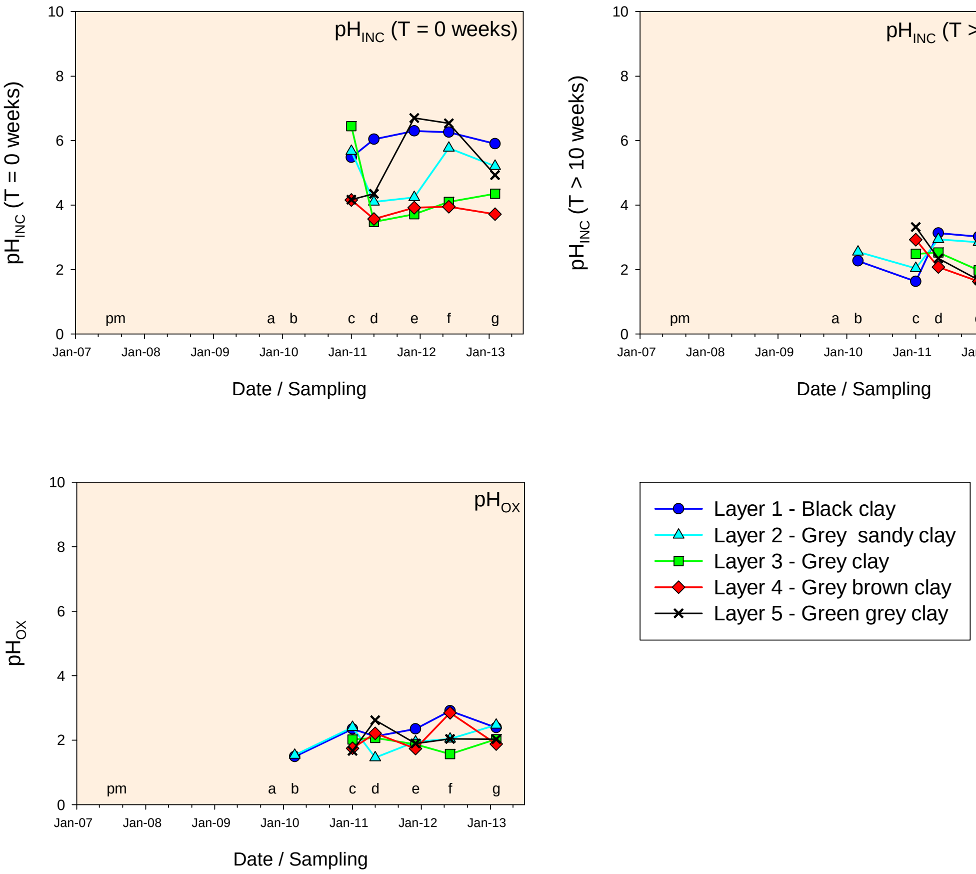


Figure A-38. Plots describing the acidification potential of soil material from different depths in the soil profile through time

Table A-37 Summary of acidification potential, ASS material classification, ASS subtype classification and acidification hazard (* indicates sulfuric soil material). The soil texture in brackets following the ASS subtype classification indicates the dominant texture of the profile. The layer number refers to soil layers and corresponding data that are plotted in the previous two figures. NC: non-continuous soil layers that were not encountered during the majority of samplings

Sample	Sampling	Layer	Depth (cm)	pH_{OX} < 2.5	pH_{INC} < 4.0	NA > 0	Acidification potential	ASS material classification	ASS subtype	Acidification hazard
LF20-A										
LFb20-A.1	b	NC	0-0.5	1	1	1	3*	Sulfuric sandy clay	Sulfuric clay soil (clay)	**High**
LFb20-A.2		NC	0.5-5	1	1	1	3*	Sulfuric sandy clay		
LFb20-A.3		1	5-25	1	1	1	3*	Sulfuric sandy clay		
LFb20-A.4		2	25-45	1	1	1	3*	Sulfuric sandy clay		
LFc20-A.1	c	1	0-26	1	1	1	3	Hypersulfidic sandy clay	Hypersulfidic subaqueous clay soil (clay)	**High**
LFc20-A.2		2	26-36	1	1	1	3	Hypersulfidic sandy clay		
LFc20-A.3		3	36-49	1	1	1	3	Hypersulfidic sandy clay		
LFc20-A.4		4	49-65	1	1	1	3	Hypersulfidic clay		
LFd20-A.1	d	1	0-6	1	1	1	3	Hypersulfidic clay	Sulfuric subaqueous clay soil (clay)	**High**
LFd20-A.2		2	6-15	1	1	1	3	Hypersulfidic clay		
LFd20-A.3		3	15-29	1	1	1	3*	Sulfuric clay		
LFd20-A.4		4	29-55	1	1	1	3*	Sulfuric clay		
LFd20-A.5		5	55-78	0	1	1	2	Hypersulfidic clay		
LFe20-A.1	e	1	0-10	1	1	1	3	Hypersufilidic medium clay	Sulfuric subaqueous clay soil (clay)	**High**
LFe20-A.2		2	10-17	1	1	1	3	Hypersufilidic medium clay		
LFe20-A.3		3	17-30	1	1	1	3*	Sulfuric medium clay		
LFe20-A.4		4	30-55	1	1	1	3*	Sulfuric medium clay		
LFe20-A.5		5	55-89	1	1	1	3	Hypersufilidic medium clay		
LFf20-A.1	f	1	0-8	0	1	1	2	Hypersufilidic heavy clay	Hypersulfidic subaqueous clay soil (clay)	**High**
LFf20-A.2		2	8-18	1	1	1	3	Hypersufilidic heavy clay		
LFf20-A.3		3	18-42	1	1	1	3	Hypersufilidic heavy clay		
LFf20-A.4		4	42-57	0	1	1	2	Hypersufilidic heavy clay		
LFf20-A.5		5	57-92	1	1	1	3	Hypersufilidic heavy clay		
LFg20-A.1	g	1	0-12	1	1	1	3	Hypersulfidic sandy clay	Hypersulfidic subaqueous clay soil (clay)	**High**
LFg20-A.3		3	20-35	1	1	1	3	Hypersulfidic sandy clay		
LFg20-A.4		4	35-60	1	1	1	3	Hypersulfidic heavy clay		
LFg20-A.5		5	60-80	1	1	1	3	Hypersulfidic heavy clay		

Table A-38. Summary of temporal changes in ASS Classification, acidification hazard [1](**H** = High; **M** = medium; **L** = Low; **VL** = Very Low), site condition and profile chemistry and morphology (Refer to previous two figures and table)

Sampling	[1]ASS Classification & [2]Acidification hazard	Site photographs	Notes
Drought End summer 2010 (b)	**Sulfuric* clay (H)**		During the extreme drought period (2007 to 2009) soil remained Sulfuric. Inundation, following winter 2010, caused the formation of Hypersulfidic and Sulfuric subaqueous soil. Prolonged inundation caused the formation of Hypersulfidic subaqueous soil.
Post-drought Summer 2011 (c)	**Sulfuric* subaqueous clay (H)**		
Post-drought Winter 2011 (d)	**Sulfuric* subaqueous clay (H)**		
Post-drought Start summer 2011/12 (e)	**Sulfuric* subaqueous clay (H)**		
Post-drought Start winter 2012 (f)	**Hypersulfidic subaqueous clay (H)**		
Post-drought Summer 2013 (g)	**Hypersulfidic subaqueous clay (H)**		

LF20-B

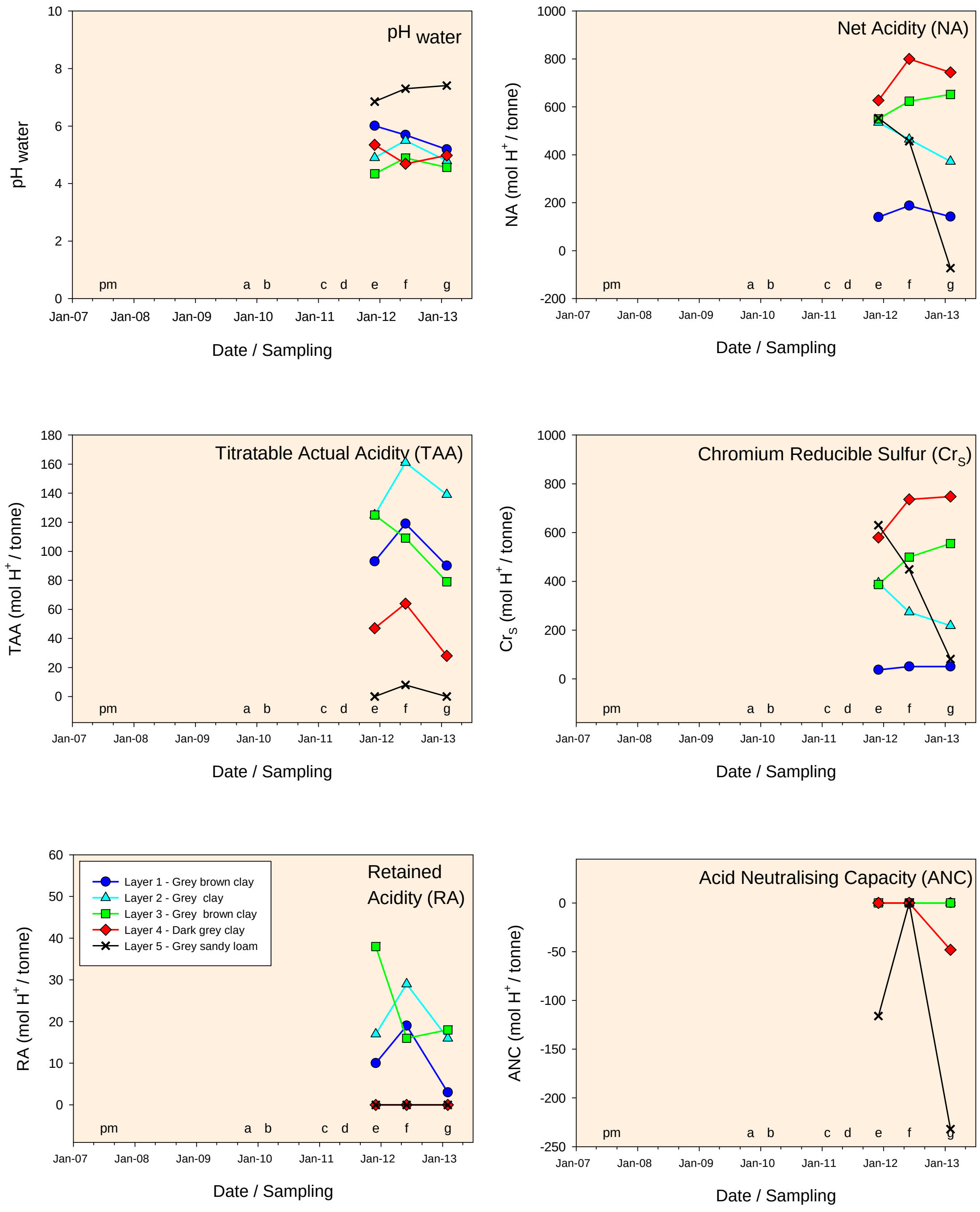


Figure A-39. Plots describing the location and quantity of acidity and acid neutralisation capacity within the soil profile and how this alters through time in response to drought and subsequent reflooding

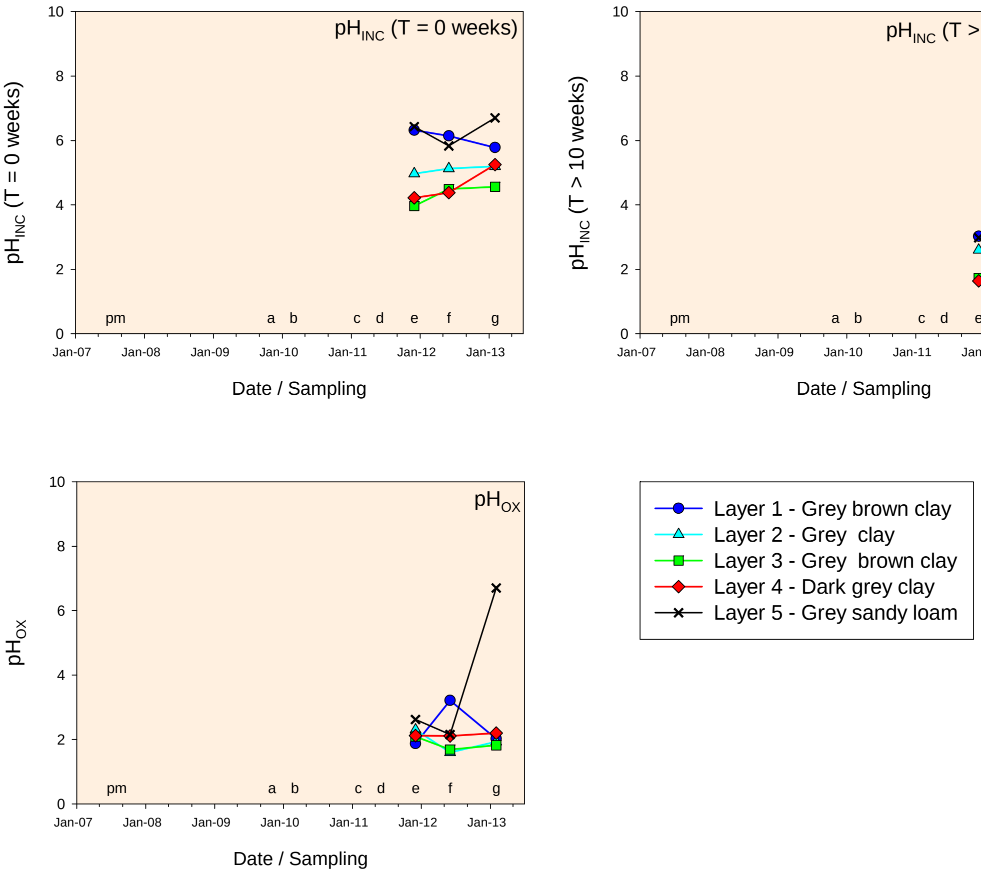


Figure A-40. Plots describing the acidification potential of soil material from different depths in the soil profile through time

Table A-39 Summary of acidification potential, ASS material classification, ASS subtype classification and acidification hazard (* indicates sulfuric soil material). The soil texture in brackets following the ASS subtype classification indicates the dominant texture of the profile. The layer number refers to soil layers and corresponding data that are plotted in the previous two figures. NC: non-continuous soil layers that were not encountered during the majority of samplings

Sample	Sampling	Layer	Depth (cm)	pH$_{OX}$ < 2.5	pH$_{INC}$ < 4.0	NA > 0	Acidification potential	ASS material classification	ASS subtype	Acidification hazard
LF20-B										
LFe20-B.1	e	1	0-8	1	1	1	**3**	Hypersufilidic heavy clay	Hypersulfidic subaqueous clay soil (clay)	**High**
LFe20-B.2		2	8-16	1	1	1	**3**	Hypersufilidic heavy clay		
LFe20-B.3		3	16-38	1	1	1	**3**	Hypersufilidic heavy clay		
LFe20-B.4		4	38-58	1	1	1	**3**	Hypersufilidic heavy clay		
LFe20-B.5		5	58-66	0	1	1	2	Hypersufilidic sandy loam		
LFe20-B.6		6	66-80	0	0	0	0	Hyposulfidic heavy clay		
LFf20-B.1	f	1	0-11	0	1	1	2	Hypersufilidic heavy clay	Hypersulfidic subaqueous clay soil (clay)	**High**
LFf20-B.2		2	11-20	1	1	1	**3**	Hypersufilidic heavy clay		
LFf20-B.3		3	20-35	1	1	1	**3**	Hypersufilidic heavy clay		
LFf20-B.4		4	35-60	1	1	1	**3**	Hypersufilidic heavy clay		
LFf20-B.5		5	60-70	1	1	1	**3**	Hypersufilidic sandy loam		
LFg20-B.1	g	1	0-15	1	1	1	**3**	Hypersufilidic sandy clay	Hypersulfidic subaqueous clay soil (clay)	**High**
LFg20-B.2		2	15-27	1	1	1	**3**	Hypersufilidic heavy clay		
LFg20-B.3		3	27-47	1	1	1	**3**	Hypersufilidic sandy clay		
LFg20-B.4		4	47-67	1	1	1	**3**	Hypersufilidic clayey sand		
LFg20-B.5		5	67-80	0	0	0	0	Hyposulfidic silty sand		

Table A-40. Summary of temporal changes in ASS Classification, acidification hazard [1](**H** = High; **M** = medium; **L** = Low; **VL** = Very Low), site condition and profile chemistry and morphology (Refer to previous two figures and table)

Sampling	[1]**ASS Classification & [2]Acidification hazard**	**Site photographs**	**Notes**
Post-drought Start summer 2011/12 (e)	**Hypersulfidic subaqueous clay (H)**		Following inundation in winter 2010, soil material remained Hypersulfidic subaqueous clay soil.
Post-drought Start winter 2012 (f)	**Hypersulfidic subaqueous clay (H)**		
Post-drought Summer 2013 (g)	**Hypersulfidic subaqueous clay (H)**		

A.15 LF21: Windmill Site

LF21-A

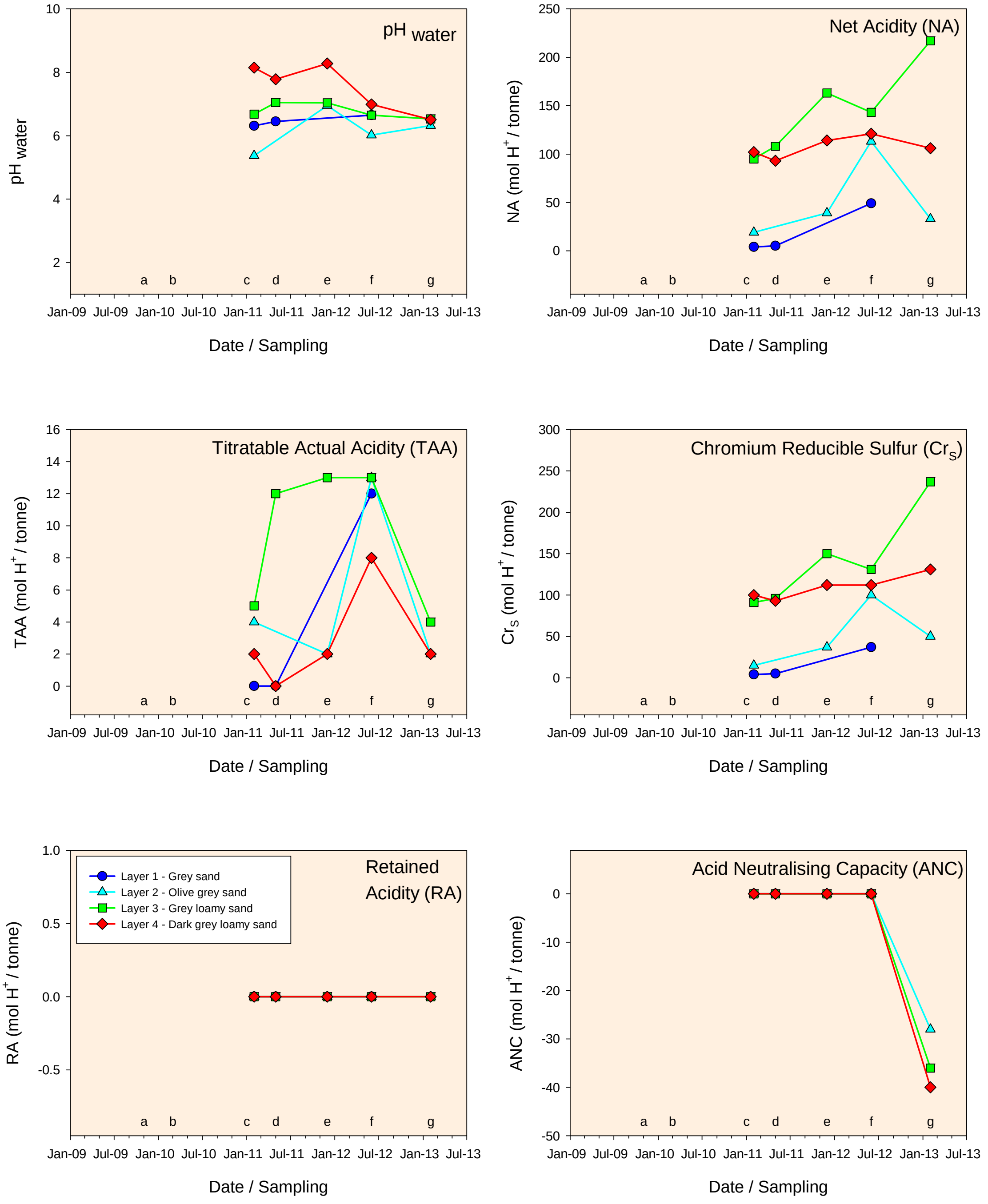


Figure A-41. Plots describing the location and quantity of acidity and acid neutralisation capacity within the soil profile and how this alters through time in response to drought and subsequent reflooding

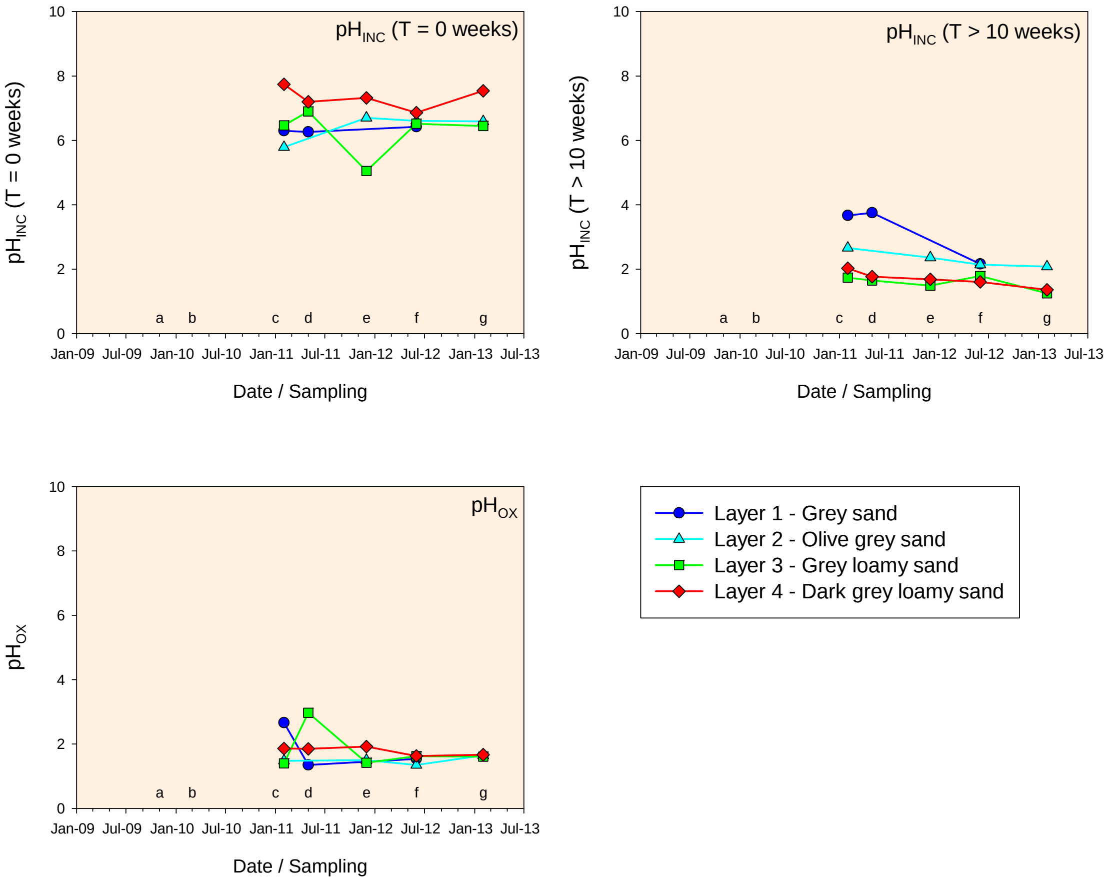


Figure A-42. Plots describing the acidification potential of soil material from different depths in the soil profile through time

Table A-41 Summary of acidification potential, ASS material classification, ASS subtype classification and acidification hazard (* indicates sulfuric soil material). The soil texture in brackets following the ASS subtype classification indicates the dominant texture of the profile. The layer number refers to soil layers and corresponding data that are plotted in the previous two figures. NC: non-continuous soil layers that were not encountered during the majority of samplings

Sample	Sampling	Layer	Depth (cm)	pH_{OX} < 2.5	pH_{INC} < 4.0	NA > 0	Acidification potential	ASS material classification	ASS subtype	Acidification hazard
LF21-A										
LFc21-A.1	c	1	0-7	0	1	1	2	Sand	Hypersulfidic subaqueous soil (sand)	**High**
LFc21-A.2		2	7-14	1	1	1	**3**	Hypersulfidic sand		
LFc21-A.3		3	14-36	1	1	1	**3**	Hypersulfidic loamy sand		
LFc21-A.4		4	36-62	1	1	1	**3**	Hypersulfidic loamy sand		
LFd21-A.1	d	1	0-7	1	1	1	**3**	Sand	Hypersulfidic subaqueous soil (sand)	**High**
LFd21-A.2		3	7-37	0	1	1	2	Hypersulfidic loamy sand		
LFd21-A.3		4	37-65	1	1	1	**3**	Hypersulfidic clay		
LFe21-A.1	e	2	0-16	1	1	1	**3**	Hypersufilidic sand	Hypersulfidic subaqueous soil (sand)	**High**
LFe21-A.2		3	16-32	1	1	1	**3**	Hypersufilidic sand		
LFe21-A.3		4	32-59	1	1	1	**3**	Hypersufilidic loamy sand		
LFf21-A.1	f	1	0-6	1	1	1	**3**	Hypersufilidic sand	Hypersulfidic subaqueous soil (sand)	**High**
LFf21-A.2		2	6-26	1	1	1	**3**	Hypersufilidic sand		
LFf21-A.3		3	26-47	1	1	1	**3**	Hypersufilidic sand		
LFf21-A.4		4	47-67	1	1	1	**3**	Hypersufilidic loamy sand		
LFg21-A.1	g	2	0-14	1	1	1	**3**	Hypersufilidic sand	Hypersulfidic subaqueous soil (sand)	**High**
LFg21-A.2		3	14-54	1	1	1	**3**	Hypersufilidic sand		
LFg21-A.3		4	54-74	1	1	1	**3**	Hypersufilidic sand		

Table A-42. Summary of temporal changes in ASS Classification, acidification hazard [1](**H** = High; **M** = medium; **L** = Low; **VL** = Very Low), site condition and profile chemistry and morphology (Refer to previous two figures and table)

Sampling	[1]ASS Classification & [2]Acidification hazard	Site photographs	Notes
Post-drought Summer 2011 (c)	**Hypersulfidic subaqueous (H)**		Following inundation in winter 2010, soil material remained Hypersulfidic subaqueous.
Post-drought Winter 2011 (d)	**Hypersulfidic subaqueous (H)**		
Post-drought Start summer 2011/12 (e)	**Hypersulfidic subaqueous (H)**		
Post-drought Start winter 2012 (f)	**Hypersulfidic subaqueous (H)**		
Post-drought Summer 2013 (g)	**Hypersulfidic subaqueous (H)**		

A.16 LF23: Lower Currency

LF23-A

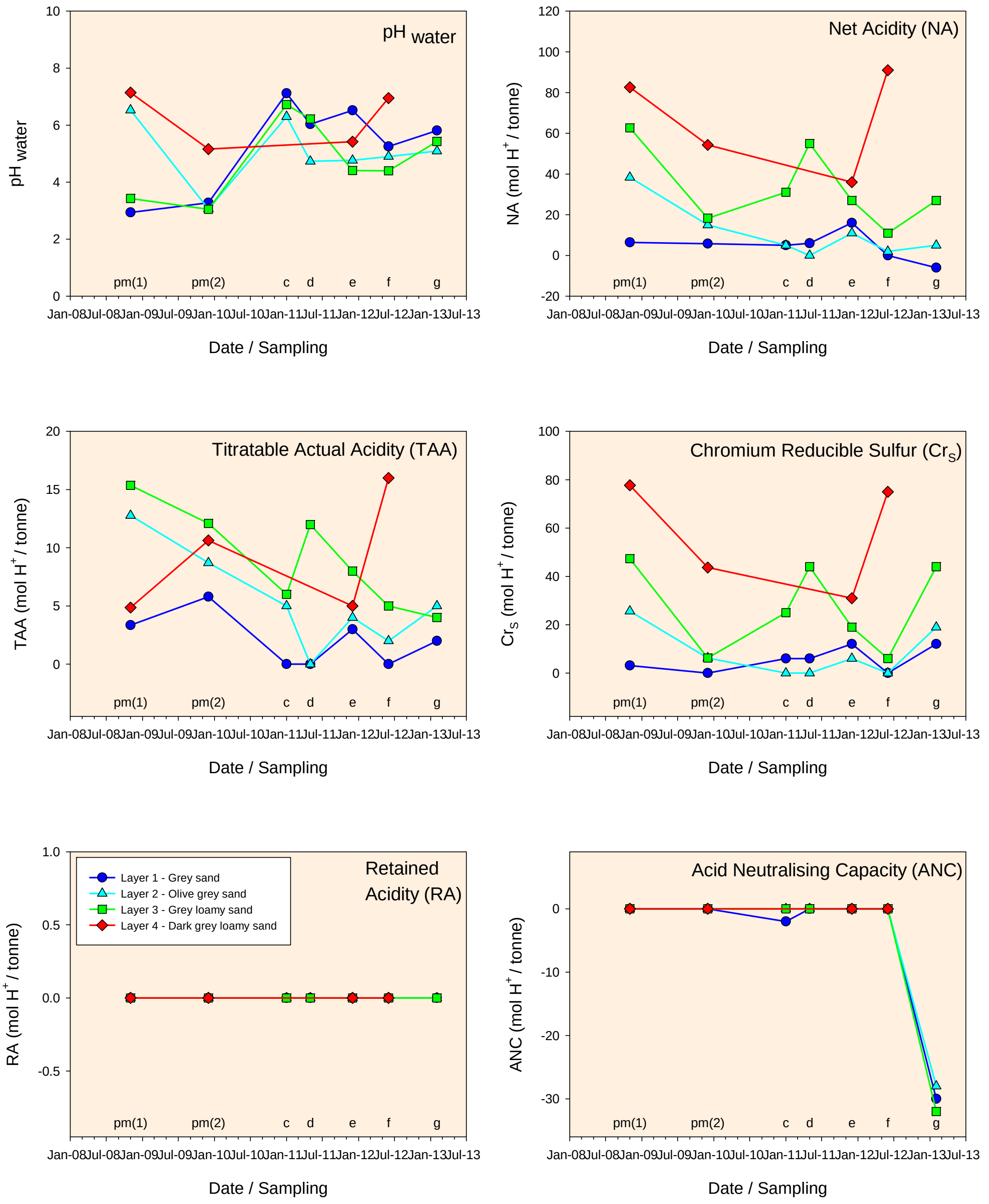


Figure A-43. Plots describing the location and quantity of acidity and acid neutralisation capacity within the soil profile and how this alters through time in response to drought and subsequent reflooding

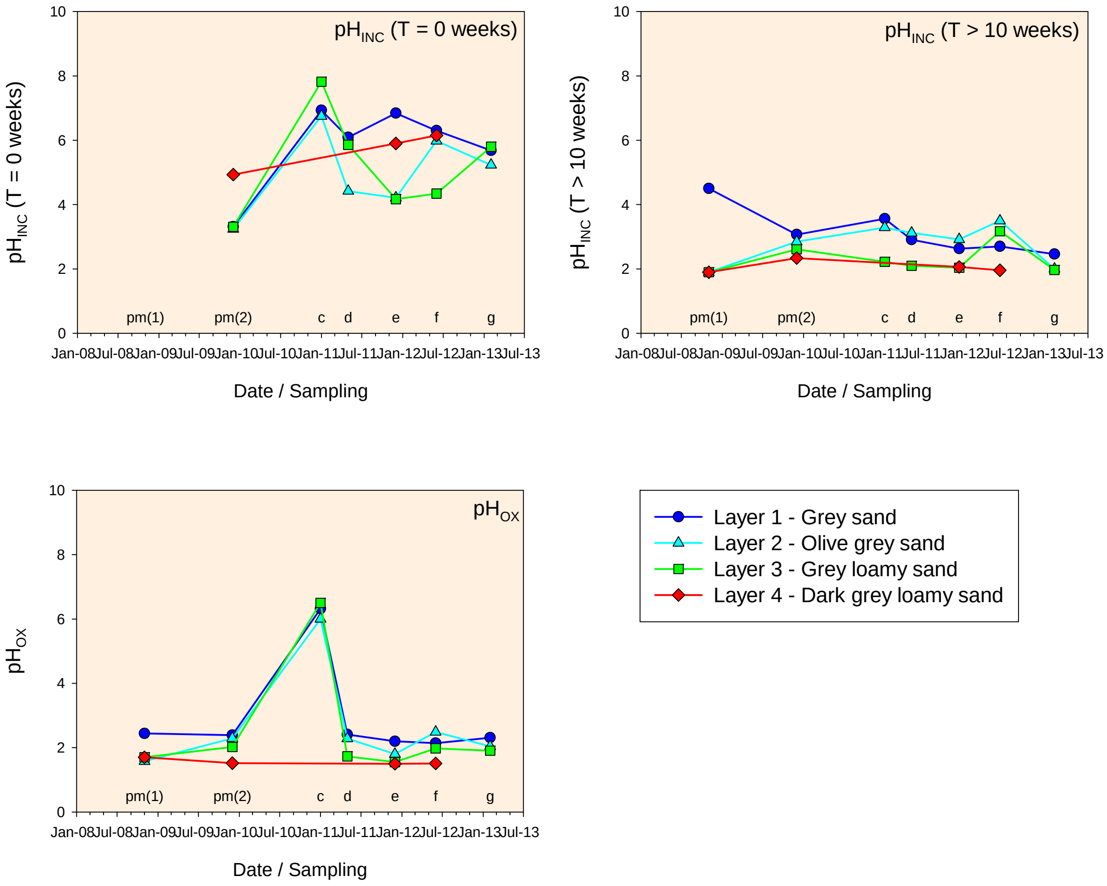


Figure A-44. Plots describing the acidification potential of soil material from different depths in the soil profile through time

Table A-43 Summary of acidification potential, ASS material classification, ASS subtype classification and acidification hazard (* indicates sulfuric soil material). The soil texture in brackets following the ASS subtype classification indicates the dominant texture of the profile. The layer number refers to soil layers and corresponding data that are plotted in the previous two figures. NC: non-continuous soil layers that were not encountered during the majority of samplings

Sample	Sampling	Layer	Depth (cm)	pH_{OX} < 2.5	pH_{INC} < 4.0	NA > 0	Acidification potential	ASS material classification	ASS subtype	Acidification hazard
LF23-A										
LFh(1)23-A.1	pm(1)	NC	0 - 0.5	0	0	0	0	Sand	Sulfuric soil (sand)	**High**
LFh(1)23-A.2		1	0.5 - 10	1	0	1	2*	Sulfuric loamy sand		
LFh(1)23-A.3		2	10-25	1	1	1	**3**	Hypersulfidic loamy sand		
LFh(1)23-A.4		3	25 - 35	1	1	1	**3***	Sulfuric loamy sand		
LFh(1)23-A.5		4	35 - 60	1	1	1	**3**	Hypersulfidic loamy sand		
LFh(2)23-A.1	pm(2)	NC	0 - 2	1	0	0	1	Hyposulfidic sand	Sulfuric soil (sand)	**High**
LFh(2)23-A.2		1	2-15	1	1	1	**3***	Sulfuric loamy sand		
LFh(2)23-A.3		2	15 - 30	1	1	1	**3***	Sulfuric loamy sand		
LFh(2)23-A.4		3	30 - 60	1	1	1	**3***	Sulfuric loamy sand		
LFh(2)23-A.5		4	60 - 90	1	1	1	**3**	Hypersulfidic loamy sand		
LFc23-A.1	c	1	0-12	0	1	1	2	Hypersulfidic sand	Hypersulfidic subaqueous soil (sand)	**Medium**
LFc23-A.2		2	12-33	0	1	1	2	Sand		
LFc23-A.3		3	33-46	0	1	1	2	Hypersulfidic sand		
LFd23-A.1	d	1	0-10	1	1	1	**3**	Hypersulfidic sand	Hypersulfidic subaqueous soil (sand)	**High**
LFd23-A.2		2	10-28	1	1	0	2	Sand		
LFd23-A.3		3	28-54	1	1	1	**3**	Hypersulfidic loamy sand		
LFe23-A.1	e	1	0-7	1	1	1	**3**	Hypersufilidic sand	Hypersulfidic subaqueous soil (sand)	**High**
LFe23-A.2		2	7-26	1	1	1	**3**	Hypersufilidic sand		
LFe23-A.3		3	26-40	1	1	1	**3**	Hypersufilidic sand		
LFe23-A.4		4	40-54	1	1	1	**3**	Hypersufilidic sand		
LFf23-A.1	f	1	0-8	1	1	0	2	Loamy sand	Hypersulfidic subaqueous soil (sand)	**Medium**
LFf23-A.2		2	8-25	1	1	1	**3**	Sand		
LFf23-A.3		3	25-49	1	1	1	**3**	Hypersufilidic sand		
LFf23-A.4		4	49-75	1	1	1	**3**	Hypersufilidic sand		
LFf23-A.5		5	75-83	1	1	1	**3**	Hypersufilidic sand		
LFg23-A.1	g	1	0-7	1	1	0	2	Hypersufilidic sand	Hypersulfidic subaqueous soil (sand)	**Medium**
LFg23-A.2		2	7-24	1	1	1	**3**	Hypersufilidic clayey sand		
LFg23-A.3		3	24-74	1	1	1	**3**	Hypersufilidic sand		

Table A-44. Summary of temporal changes in ASS Classification, acidification hazard [1](**H** = High; **M** = medium; **L** = Low; **VL** = Very Low), site condition and profile chemistry and morphology (Refer to previous two figures and table)

Sampling	**[1]ASS Classification & [2]Acidification hazard**	**Site photographs**	**Notes**
Pre-monitoring Drought Pre-regulator Start summer 2008 (pm(1))	**Sulfuric (H)**		During the extreme drought period (2007 to 2009) soil remained Sulfuric. Inundation, following construction of the Clayton regulator in 2009, caused the formation of Hypersulfidic subaqueous soil.
Pre-monitoring Drought Post-regulator Summer 2009 (pm(2))	**Sulfuric (H)**		
Post-drought Summer 2011 (c)	**Hypersulfidic subaqueous (M)**		
Post-drought Winter 2011 (d)	**Hypersulfidic subaqueous (H)**		
Post-drought Start summer 2011/12 (e)	**Hypersulfidic subaqueous (H)**		
Post-drought Start winter 2012 (f)	**Hypersulfidic subaqueous (M)**		
Post-drought Summer 2013 (g)	**Hypersulfidic subaqueous (M)**		

A.17 LF24: Lower Finniss

LF24-A

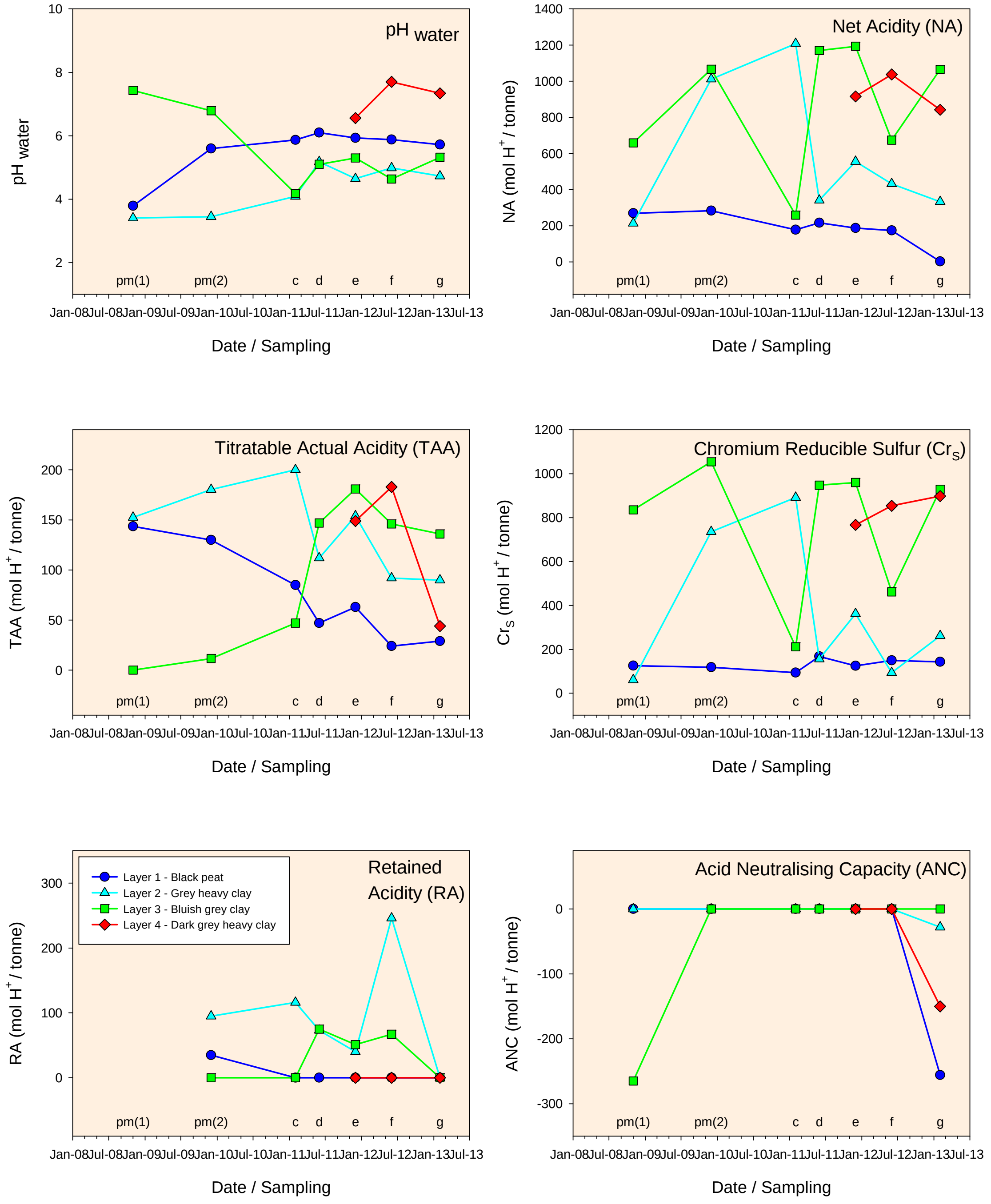


Figure A-45. Plots describing the location and quantity of acidity and acid neutralisation capacity within the soil profile and how this alters through time in response to drought and subsequent reflooding

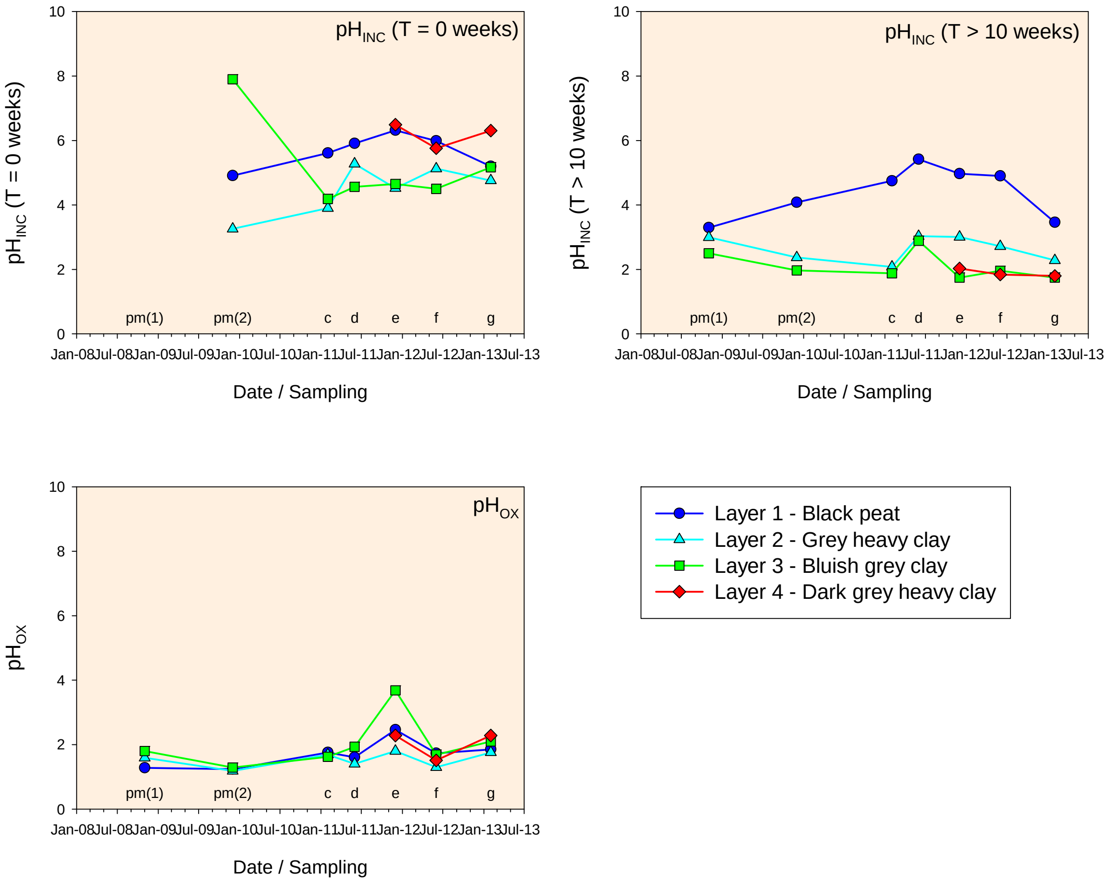


Figure A-46. Plots describing the acidification potential of soil material from different depths in the soil profile through time

Table A-45 Summary of acidification potential, ASS material classification, ASS subtype classification and acidification hazard (* indicates sulfuric soil material). The soil texture in brackets following the ASS subtype classification indicates the dominant texture of the profile. The layer number refers to soil layers and corresponding data that are plotted in the previous two figures. NC: non-continuous soil layers that were not encountered during the majority of samplings

Sample	Sampling	Layer	Depth (cm)	pH_{OX} < 2.5	pH_{INC} < 4.0	NA > 0	Acidification potential	ASS material classification	ASS subtype	Acidification hazard
LF24-A										
LFh(1)24-A.1	pm(1)		0 - 10	1	1	1	**3***	Sulfuric clay	Sulfuric clay soil (clay)	**High**
LFh(1)24-A.2			10-18	1	1	1	**3***	Sulfuric clay		
LFh(1)24-A.3			18 - 45	1	1	1	**3***	Sulfuric clay		
LFh(1)24-A.4			45 - 150	1	1	1	**3**	Hypersulfidic clay		
LFh(2)24-A.1	pm(2)		0 - 6	1	0	1	2	Hyposulfidic clay	Sulfuric clay soil (clay)	**High**
LFh(2)24-A.2			6-12	1	1	1	**3***	Sulfuric clay		
LFh(2)24-A.3			12-25	1	1	1	**3***	Sulfuric clay		
LFh(2)24-A.4			25 - 50	1	1	1	**3**	Hypersulfidic clay		
LFc24-A.1	c	1	0-15	1	0	1	2	Hyposulfidic clay	Hypersulfidic subaqueous clay soil (clay)	**High**
LFc24-A.2		NC	15-30	1	1	1	**3**	Hypersulfidic fibric peat		
LFc24-A.3		2	30-55	1	1	1	**3**	Hypersulfidic clay		
LFc24-A.4		3	55-70	1	1	1	**3**	Hypersulfidic clay		
LFd24-A.1	d	1	0-27	1	0	1	2	Hyposulfidic sapric peat	Hypersulfidic subaqueous clay soil (clay)	**High**
LFd24-A.2		2	27-46	1	1	1	**3**	Hypersulfidic clay		
LFd24-A.3		3	46-70	1	1	1	**3**	Hypersulfidic clay		
LFe24-A.1	e	1	0-28	1	0	1	2	Hyposulfidic peat	Hypersulfidic subaqueous clay soil (clay)	**High**
LFe24-A.2		2	28-42	1	1	1	**3**	Hypersufilidic heavy clay		
LFe24-A.3		3	42-52	0	1	1	2	Hypersufilidic heavy clay		
LFe24-A.4		4	52-87	1	1	1	**3**	Hypersufilidic heavy clay		
LFf24-A.1	f	1	0-28	1	0	1	2	Hyposulfidic sapric peat	Hypersulfidic subaqueous clay soil (clay)	**High**
LFf24-A.2		2	28-37	1	1	1	**3**	Hypersufilidic heavy clay		
LFf24-A.3		3	37-57	1	1	1	**3**	Hypersufilidic heavy clay		
LFf24-A.4		4	57-76	1	1	1	**3**	Hypersufilidic heavy clay		
LFg24-A.1	g	1	0-30	1	1	1	**3**	Hypersufilidic hemic peat	Hypersulfidic subaqueous clay soil (clay)	**High**
LFg24-A.2		2	30-40	1	1	1	**3**	Hypersufilidic heavy clay		
LFg24-A.3		3	40-60	1	1	1	**3**	Hypersufilidic heavy clay		
LFg24-A.4		4	60-85	1	1	1	**3**	Hypersufilidic heavy clay		

Table A-46. Summary of temporal changes in ASS Classification, acidification hazard [1](**H** = High; **M** = medium; **L** = Low; **VL** = Very Low), site condition and profile chemistry and morphology (Refer to previous two figures and table)

Sampling	**[1]ASS Classification & [2]Acidification hazard**	**Site photographs**	**Notes**
Pre-monitoring Drought Pre-regulator Start summer 2008 (pm(1))	**Sulfuric clay (H)**		During the extreme drought period (2007 to 2009) soil remained Sulfuric. Inundation, following construction of the Clayton regulator in 2009, caused the formation of Hypersulfidic subaqueous soil.
Pre-monitoring Drought Post-regulator Summer 2009 (pm(2))	**Sulfuric* subaqueous clay (H)**		
Post-drought Summer 2011 (c)	**Hypersulfidic subaqueous clay (H)**		
Post-drought Winter 2011 (d)	**Hypersulfidic subaqueous clay (H)**		
Post-drought Start summer 2011/12 (e)	**Hypersulfidic subaqueous clay (H)**		
Post-drought Start winter 2012 (f)	**Hypersulfidic subaqueous clay (H)**		
Post-drought Summer 2013 (g)	**Hypersulfidic subaqueous clay (H)**		

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