Assessment of saturated hydraulic conductivity in coastal floodplain acid sulfate soils

Phillip Hirst [A], Peter Slavich [B,] Scott Johnston [C] and Simon Walsh [B]

[A]Industry and Investment NSW, Grafton Agricultural Research Station, PMB 2, Grafton, NSW 2460, Australia, Email phillip.hirst@industry.nsw.gov.au
[B]Industry and Investment NSW, Wollongbar Agricultural Institute, Bruxner Highway, NSW 2477, Australia.
[C]Southern Cross University GeoScience, Lismore, NSW 2480 Australia.

Key Words
Hydraulic conductivity, acid sulfate soil, macropores, floodplain.

Introduction
Coastal acid sulphate soils (CASS) typically contain large stores of soluble acidity and trace metals which can be mobilised and transported to adjacent waterways, causing considerable environmental degradation (Minh *et al*. 1997; Johnston *et al*. 2004a). The main transport pathway of acidic products to drainage systems for soils with macropores in the sulphuric horizon is by saturate flow of groundwater (Bouma *et al.* 1993; Eriksson, 1993; Minh *et al*. 2002; Johnston *et al.* 2004a). Consequently the saturated hydraulic conductivity (K_{sat}) of the sulfuric horizon is an important soil property to evaluate when developing remediation strategies to reduce acid export. CASS typically have distinct soil horizons with large vertical gradients in their physical and geochemical properties due to their unique pedogenesis. Pedogenesis after drainage follows a sequential progression involving physical 'ripening', whereby the drying of gel-like sulfidic material leads to partially irreversible clay shrinkage and increasing development of cracks, plus the production of severe acidity via oxidation of sulfides (Dent 1986). A typical acid sulfate soil profile consists of an oxidised, acidic, sulfuric horizon overlying unoxidised, sulfidic material, with a transition zone of variable thickness in-between. The overlying sulfuric horizon generally has far greater structure development than the underlying sulfidic horizon. This difference in physical structure can result in radically contrasting hydraulic properties between sulfuric and sulfidic soil horizons, whereby the K_{sat} decreases markedly with depth (Thi Minh Hue Le *et al*. 2008). Knowledge of the range and variability of Ksat within sulfuric horizons CASS floodplains and between floodplain catchments is currently very limited. This study explores the variability of sulfuric horizon K_{sat} on seven major CASS floodplains in northern NSW Australia (Figure 1) using a single methodology to provide a statistically robust assessment of the likely range and variability of Ksat occurring within these soils. A major component of the study was the informal, hands-on training opportunity for local council floodplain officers to conduct the simple and semi-quantitative K_{sat} pit test and to analyse and interpret data.

Materials and methods
The methodology for assessing K_{sat} of sulfuric horizons was an *in situ* recovery technique, (Johnston and Slavich 2003; Bower H 1989; Bower *et al.* 1983), conducted in ~0.4–0.65 m deep pits. Duplicate recovery tests were conducted in a total of 148 pits located in 32 separate geomorphic units. An important advantage of the *in situ* techniques is their measure of actual aquifer response and also they avoid potential problems of soil deformation and alteration of pore continuity associated with ex-situ techniques (Bouma 1991). Surveying was conducted on seven Holocene coastal floodplains known to contain acid sulfate soils located in northern NSW, eastern Australia (Figure 1, 28^o 10' to 32^o 40' S, 152^o 12' to 153^o 30' E). Most locations were situated in landscapes assessed and mapped as having a 'high risk' of acid sulfate soils within 1 m of the surface. Pit selection included consultation with local floodplain officers scrutinizing capacity planning and/or implementing site remediation strategies. Field assessment also included groundwater pH and EC measurements, GPS sited, soil profile descriptions, and macropore observations.

Results and Discussion
K_{sat} spanned four orders of magnitude, ranging from <0.5 m day−1 to >500 m day−1. (Assessment of K_{sat} report to councils 2009, Johnston *et al.* 2009). These data indicates that 48% of pits in the range of >15 m day-1 (*High to Extreme*), and 18% of data come from locations with K_{sat} rates >100 m day-1 (*Extreme range*) (Figure 3). The standard deviation analysis (Figure 4) of site means (K_{sat} values from pits per locale), illustrates the inherently high degree of landscape variability in K_{sat} values. It also reflects the resilience of the pit bailing technique in contrasting CASS backswamp environments. An inter-floodplain comparison on

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range of sulfuric horizon K_{sat} (Figure 2), clearly demonstrates that the occurrence of very high K_{sat} values in sulfuric horizons is not an isolated phenomenon, as it occurs on most of the CASS floodplains examined in our study.

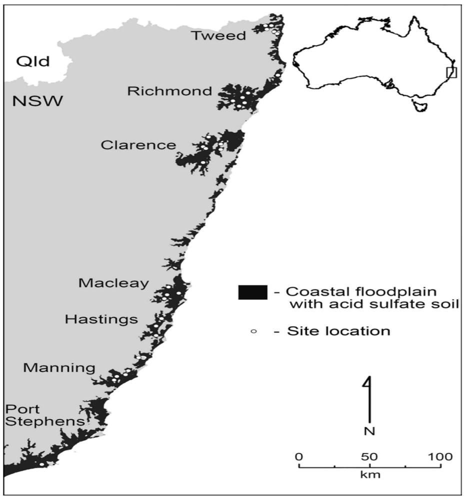

Figure 1. K_{sat} test site locations in relation to coastal floodplains with acid sulfate soils.

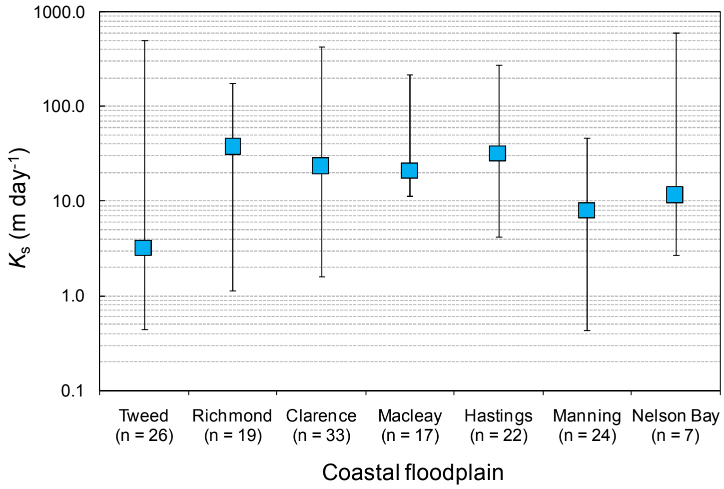

Figure 2. A comparison of the median (box) and range (error bars) of K_{sat} for all floodplains surveyed, where (n) = number of individual K_{sat} pits per floodplain. K_{sat} data calculated using Bouwer and Rice, 1983.

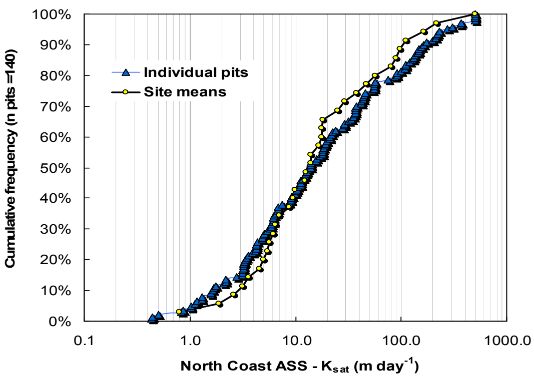

Figure 3. The cumulative frequency of K_{sat} for individual pits and site means (note: log scale x-axis).

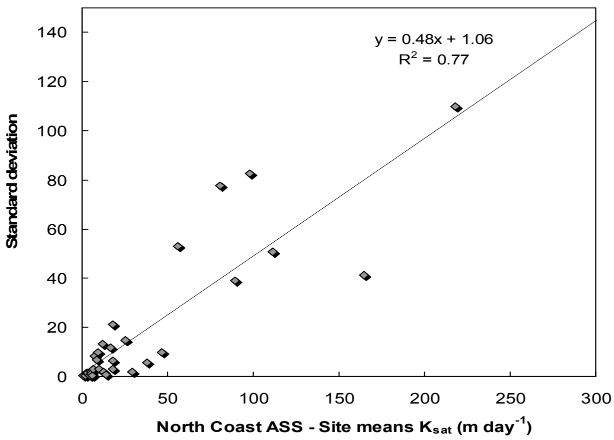

Figure 4: Standard deviation analysis on K_{sat} site means.

Conclusion

The study data on CASS demonstrates that sulfuric horizon K_{sat} is capable of being extraordinarily high, that high K_{sat} is relatively common, and can be extremely variable within individual floodplains. Visual observations confirm that high K_{sat} values were strongly associated with macropore flow, which highlights the need to use techniques for measuring K_{sat} in sulfuric horizons that are both *in situ* and of an appropriate scale: as small volume and ex-situ laboratory based techniques are highly prone to yield unrepresentative results in soils with extensive macropores (Bouma 1991). The results strongly indicate site specific assessments of sulfuric horizon K_{sat} via pit techniques or other similar *in situ* K_{sat} assessment techniques need to be included as a standard part of *risk management analysis* when making changes in backswamp hydrology during acid sulfate soil remediation projects. This is particularly important if strategies include attempts to retain acidic solutes within the landscape or involve floodgate opening and exchange of saline estuarine waters within drains.

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