Meander Loop Migration and its Effect on Liquefaction Susceptibility: Liquefaction along the Heathcote River during the 2010-12 Canterbury Earthquake Sequence

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Abstract

The majority of damage from the Canterbury Earthquake Sequence was attributed to the differential settlement of buildings and pipework caused by liquefaction and lateral spreading, particularly within the inside bends of modern and palaeo-meander loops. The geometry of accumulated facies preserved in a channel belt is dependent on the rate of meander migration and associated changes in grain-size distributions. Geomorphic changes in river channels influence the distribution of liquefiable layers while the age of such sediments, thickness and the amount of compaction also affect the ability of these layers to liquefy. Linking the deposition of successive fluvial deposits and liquefaction susceptibility requires an understanding of facies associations in migrating meander loops. This study involves distinguishing how changing terrestrial depositional systems and previous channel geomorphology affect spatial changes in grain size distributions within meander loops and how these deposits relate to the dispersal of damage from the Canterbury Earthquake Sequence.

New Zealand Earthquake Commission (EQC) liquefaction reports and aerial photography taken following the Canterbury earthquakes show the suburb of St Martins, adjacent to the Heathcote River, experienced moderate to server quantities of ejected material and subsidence. Conversely, little liquefaction was observed within the opposite suburb of Beckenham within the corresponding southward meander loop of the Heathcote River. To understand why such dramatic differences in liquefaction distributions occurred the properties of sediments within the inner meander loops and point bar deposits in the migrating river system are examined. Former river channels and abandoned meanders consist of loose sand and silt deposits and therefore the properties of these sediments exert a critical control on the susceptibility of liquefaction during an earthquake. The dispersal of saturated sand dominant facies at shallow depths along the Heathcote River determined the extent of settlement during the Canterbury earthquakes, through liquefaction, which is related to the evolution of the river channel. Differential LiDAR (Light Detection and Ranging) spatial analysis and the compilation of post-earthquake surface deformation data shows where the majority of liquefaction-induced settlement was focused across St Martins. This data combined with elevation models identify the location of a palaeo-channel, which displays similar fluvial architecture to the meander loop geometry. Targeted trenching, hand augers and interpretation of post-earthquake CPT (Cone Penetration Tests) across this area shows the severe liquefaction coincided with sand bodies (>5 m) close to the surface where the channel was once located, before migrating northward to its current position. Finer material becomes thicker and less susceptible to liquefaction either side of the palaeo-channel. Conversely the thick sand bodies are absent in the adjacent suburb of Beckenham.

The ability of meander loops to migrate and the evolution of river facies is dependent on geomorphic controls. The distribution of susceptible sand bodies in St Martins suggests the northward meander loop of the Heathcote River has been freely expanding and rotating in recent times. The thick sand deposits accumulated within the channel and have not been buried by thick flood or over bank deposits in response to the bend expansion and downstream migration. Alternatively, the expansion of the southward meander loop in Beckenham has been constrained by the

Port Hills volcanic lithologies, inhibiting channel migration. The channels inability to move has formed finer overbank and swamp deposits resistant to liquefaction.

The processes permitting meander loop migration has a critical control on sediments susceptibility to liquefaction as the critical mixtures of sands and fines (silts) required result from unique depositional environments reflecting specific water velocities and particular river geomorphic conditions. By recognising the depositional processes in curved channel segments, and how migration affects spatial changes in river facies, the impact of meander loop migration to explain sporadic distributions of liquefaction along the Heathcote River can be recognised. This research may also be applied to other meandering river systems in seismically active regions where the impacts of liquefaction may cause disruption to the built environment.