Riparian Boundaries, unintended consequences in an unconstrained environment

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Abstract This paper focuses on the boundary determination of watercourses in Queensland and options for boundary location to be realigned with the physical feature (or not), through the impact of either accretion, erosion or avulsion and is intended for practicing professionals and policymakers. The research provides insights into the legal implications of riparian boundary changes and highlights the complexities of riparian boundaries. Riparian boundaries are split into two watercourse categories, either tidal or non-tidal boundaries. If a non-tidal watercourse boundary is deemed to have moved by accretion or erosion, the boundary can move with the physical feature (ambulatory) in accordance with the *Surveying and Mapping Infrastructure Act* (2003) and the Cadastral Survey Requirements, Queensland Department of Resources (DoR). However, should the change be deemed as avulsion, the boundary does not change and remains as it was authoritatively located (current title boundary determination) prior to the First New Plan of Survey. The aim of the project is to investigate the unintended outcomes from the Doctrine of Accretion (and Erosion) in ambulatory boundary (non-tidal) determination. A case study is analysed that has experienced change in the non-tidal boundary by the processes of accretion, erosion, avulsion and man-made activity. The historical aerial imagery and cadastral plans of the case study site are analysed to map the locations of the top of bank position. The timing of the boundary changes is analysed against temporal flood events including discussion about how, why, and when the physical and non-tidal boundaries have most likely changed. The case study is assessed against the current legislation and the Doctrine of Accretion.
Keywords: Accretion

Avulsion

Ambulatory Boundary

Erosion

Non-tidal boundary

1. RIPARIAN BOUNDARIES

The occurrence of watercourses, either as irregular or regular flow and subject to rainfall or flood events make riparian boundaries a perplexing and awkward combination of law and landscape. The law struggles to precisely demarcate a riparian boundary as a fixed boundary where the feature is consistently subject to the forces of nature and dynamic with no fixed shape, other than one of conformation to the channel within which it flows. The law attempts to ameliorate the fixed versus dynamic relationship between law and landscape by adopting a natural feature as a non-tidal boundary (typically 'the bank'), where the cadastral boundary of the natural feature is defined by rules, regulations and the subjective opinion of individuals. The Doctrine of Accretion asserts that riparian change should be natural, gradual and imperceptible to effect cadastral boundary change. The doctrine applies if the change results in additional sand, soil, silt or sediment deposits that increase land (accretion) or results in the loss of land that occurs when material is removed and washed downstream and decreases land (erosion), the doctrine applies equally (Songberg 2021). If the riparian physical boundary has shifted significantly, the riparian cadastral boundary does not alter if the change is not natural or if the change is sudden and not gradual. This paper focuses on riparian ambulatory non-tidal boundary determination of watercourses in Queensland and options for boundary location to be aligned with the physical feature.

For non-tidal riparian boundaries, the bank may not be the only feature identified as a boundary, the middle of a watercourse may also be used. Non-tidal cadastral watercourse boundaries can be split into two types, neatly described by Brayley (2015) as a single line creek or a two line creek, the two types have either adjoined tenures or have physical separation by a watercourse with non-adjoined land tenures (see Figure 1):

1. contiguous (directly adjoined); or
2. non- contiguous (riparian separation and associated tenures abut a watercourse bank).

Contiguous boundaries occur where the cadastral watercourse boundary demarcates the boundary between two directly adjoined tenures (including Crown land, other examples include Parish boundaries and International and State Borders). Non-contiguous boundaries occur where the watercourse boundary demarcation defines both sides of the watercourse and the opposite banks of a watercourse form non-tidal boundaries and tenure/ownership is separated by the watercourse, either as the top of a bank above the channel or the top of a bank above the floodplain (described as the outer bank in Sect. 5A of the *Water Act 2000* (Qld)). Adopting the top of a bank for a channel allows floodplain land to be used for grazing and cropping purposes, especially if particularly fertile land and the flood plain is quite wide.

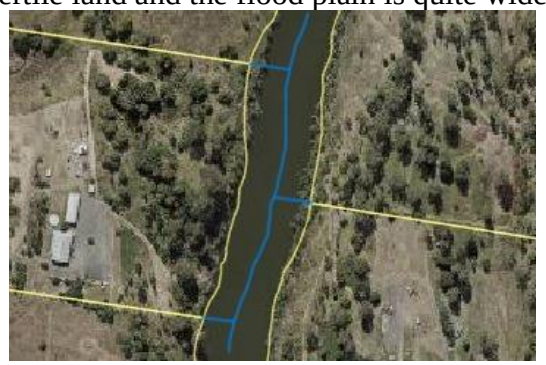

Figure 1: Sample of Cadastral watercourse boundaries (Contiguous Single line watercourse in blue and Two-line non-contiguous watercourse in yellow) (Source: Queensland Globe)

A contiguous adjoining boundary can occur when the mean line is adopted as the riparian boundary (often described by the Latin phrase *ad medium filum aquae*, meaning to the middle of a stream) where you define both banks and determine the mid-point of the watercourse. Two areas would normally be shown for the land parcel (one bounded by the bank and one bounded by the middle of the watercourse). The mid-point requires each point of the line to be equidistant from the nearest point(s) on opposite banks of a watercourse. In practical application survey-wise this presents difficulties in gaining access and travelling to land parcels on the opposite bank of the watercourse. An alternate contiguous boundary can be used for State boundaries with navigable rivers by defining the *thalweg*, being the line of deepest soundings of the watercourse (see Figure 2 for Riparian zone boundary definition).
Section 26 of the *Water Act (2000)* Qld, states "all rights to the use, flow and control of all water in Queensland are vested in the State", such that non-contiguous boundaries form the basis for riparian boundaries, in Queensland. Furthermore, Sect. 96 of the *Water Act (2000)* Qld restricts the landowner to taking water from a watercourse, lake or spring for stock or domestic purposes only. However, the State may authorise the use of water pursuant to Sect. 27 of the *Water Act (2000)* Qld allowing "the use of water by authorising persons".

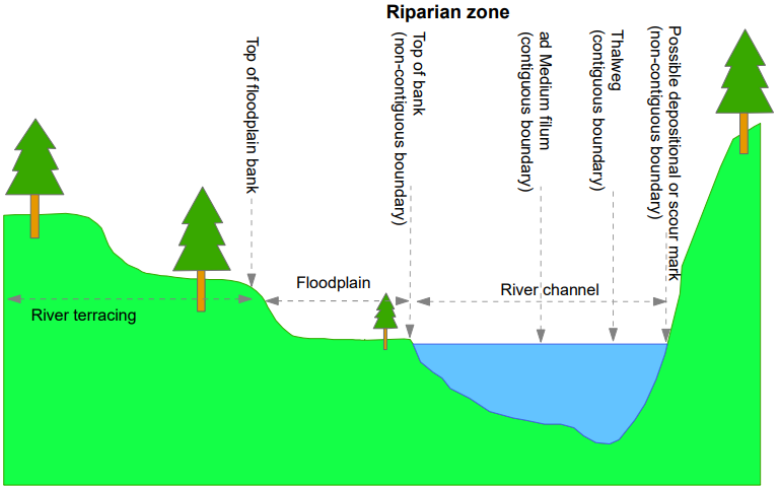

Figure 2: The Riparian zone (Image courtesy of Dr Nab Raj Subedi)

The natural forces that influence the capacity of a river to change shape are gravity, friction and fluid cohesion forces that allow the movement of water and sediment to apply a shearing action or load against the bed and banks of the channel, creating energy and movement of matter. The factors that affect this erosion are the depth of the river, quantity of water flowing through it, slope of the river, vegetation, geology of the ground and speed of the water (Janicke 2000). Although there is moderate erosion and accretion from normal low flow which only affect the lower channel, it is the rarer extreme events that can "produce major rearrangements of sediment, create new channels or drastically modify existing channels and floodplains" (Janicke 2000). Changes in the riparian zone "occur when the forces in the river flow exceed the ability of the bank and bed material to withstand those forces" (Songberg 2002).
Watercourses are susceptible to a variety of physical factors that can make the top of a bank transient or ambulatory in nature. Where a land parcel abuts a non-tidal ambulatory boundary (watercourse) and deemed to have moved by accretion (slow and gradual change), the boundary can shift with the physical feature as per the *Surveying and Mapping Infrastructure Act 2003* Qld (*SMI Act* 2003) and Department of Resources (DoR) Cadastral Survey Requirements

(CSR). Should the change be deemed as avulsion (sudden change), the boundary at law does not change and remains as authoritatively located prior to the First New Plan of Survey, Unfortunately, legislation across multiple Acts and Agencies is often confusing regarding the legislative definitions of a bank, which combined with changes of the definition of a bank as set by the various Rules and Directions issued to Surveyors, may allow for unclear outcomes. Songberg (2021) stated "the only certain thing of riparian boundary change is that it is uncertain". Figures 2(a), 2(b) and 2(c) show the movement and confusion caused by riparian change and boundary definition.

Figure 2(a): Separation of riparian boundary to the natural feature, Edmonton Qld (Source: Queensland Globe)

Figure 2(b): Confusion reigns between riparian boundaries and the Fitzroy River due to temporal change of the natural feature, Yaamba Qld (Source: Queensland Globe)

Figure 2(c): 'Adjutments (disparity between adjoining boundaries)' between surveys completed at differing temporal events, Brisbane River, Qld (Source: Queensland Globe)

If the gradual and imperceptible nature of movement of a watercourse boundary is accretion or erosion (accretion variants include alluvion and reliction, erosion variant is dereliction), the opposite process is avulsion which is a sudden or perceptible change in the watercourse. Accretion is a covert change that cannot be perceived by eye in a moment of time, whereas avulsion is sudden, perceptible and visible in an episode of time. Avulsion is distinguishable from accretion by being an event that is sudden and causes a perceptible change which exhibits both temporal and spatial elements (see Figure 3). The impacts of urban development activity and climate change related impacts will increase the likelihood of larger, more frequent floods with potentially more ambulatory boundary change from an avulsive event.

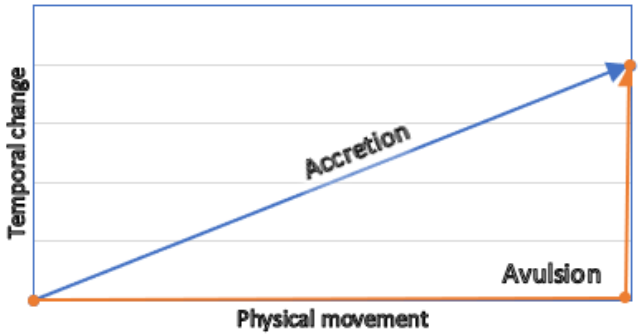

Figure 3: Accretion versus Avulsion by time and distance

Bouchez (1963) describes both accretion and avulsion as lateral movements of a river, where accretion is both gradual in time and spatially continuous whereas avulsion is the opposite and is instantaneous as regards time and is not spatially continuous and more of a sudden shift. Accretion occurs slowly over a period of time and is imperceptible spatially in a period of time, whereas avulsion occurs rapidly in time and is spatially perceptible in time. The ambulatory shift by either accretion or avulsion often results in confusion and a raft of other issues for landowners and for authorities to administer (Songberg 2002).

2. DOCTRINE OF ACCRETION

The Doctrine of Accretion originated in Roman times (Corkill 2012) and applies to boundaries of both tidal and non-tidal streams, watercourses, lakes, canals and seas where the change in the position of a tidal/non-tidal boundary is natural, gradual and imperceptible. The origin of the Doctrine of Accretion concept appears to have occurred in the sixth century AD when the Byzantine Emperor Justinian 1 (reign 527 to 565 AD) commissioned the compilation of four Books known as the Institutes of Justinian to codify imperial Roman Law. The Justinian Institutes were fundamental for the development of Western Europe's legal tradition (Streich 2017) and catalogued Roman legal tenets. Donaldson (2011) stated "drawing on Roman private property law and continuing through medieval and modern legal practice, common law jurisprudence and legal scholarship developed a distinction between the two processes of 'accretion' and 'avulsion' to mediate issues where there is a shifting river boundary".

Regarding accretion, the Justinian Institutes Book 2, the law *Concerning the Division of Things* stated "soil which a river has added to your land by alluvion becomes yours by the law of nations. Alluvion is an imperceptible addition; and that which is added so gradually that you cannot perceive the exact increase from one moment of time to another is added by alluvion". Accretion allows adjustment of a dynamic non-tidal boundary over a period of time at the time of survey. Regarding avulsion, the Justinian Institutes stated "if, however, the violence of the

stream sweeps away a parcel of your land and carries it down to the land of your neighbour it clearly remains yours". This statement is qualified by "though of course if in the process of time it becomes firmly attached to your neighbour's land, they are deemed from that time to have become part and parcel thereof." This implies once a degree of permanence is established, ownership shifts to a new non-tidal boundary position. Interestingly, the State of North Dakota applies a timeframe and limitation for reclamation by the original owner in the case of avulsion, as per the *North Dakota Century Code* (47-06-06), "if a river or stream…carries away by sudden violence a considerable and distinguishable part of a bank and bears it to the opposite bank or to another part of the same bank, the owner of the part carried away may reclaim it within a year after the owner of the land to which it has been united takes possession thereof".

The distinctions between accretion and avulsion regarding boundaries are well established by legal scholars as general principles or rules of international law. The US Supreme Court has reiterated its understanding of the distinction between accretion and avulsion in numerous boundary cases between neighbouring US states, many of which share river boundaries (Donaldson 2011). Furthermore, Donaldson (2011) commented on a *1918 Arkansas v. Tennessee case*, the Court stipulated, "when the bed and channel are changed by the natural and gradual processes known as erosion and accretion, the boundary follows the varying course of the stream; while if the stream, from any cause, natural or artificial, suddenly leaves its old bed and forms a new one by the process known as avulsion, the resulting change of channel works no change of boundary, which remains in the middle of the old channel, although no water may be flowing in it and irrespective of subsequent changes to the new channel (US, 1918). Sax (2010) highlighted inconsistencies of application by the courts in a Texas case *City of Corpus Christi v. Davis, (Tex. App. 1981),* Sax (2010) concluded it would seem like a fairly obvious case of avulsion, as the change took place as the result of a hurricane, and the expert who testified said his "understanding of avulsion changes was that such changes were 'supposed to be very sudden.'. Sax (2010) stated "while this testimony might be expected easily to have led to a finding of avulsion, that was not the result the court determined it should reach" as the Texas court said, "the application of the . . . test for 'gradual and imperceptible' resulted in holdings of erosion where the change wrought to the land has been indeed both sudden and perceptible". Sax (2010) was somewhat bemused where gradual and imperceptible is described as sudden and perceptible such that the landowners' evidence had not overcome the legal presumption in favour of accretion and the land was then vested in the state.

One of the earliest English Law court decisions involving accretion was the *Abbott of Ramsey's* case from the year 1369 (Sax 2010) and accretion/avulsion rules were shaped by the four volumes of the Commentaries on the Laws of England (1765-1770) by Sir William Blackstone (English version of the Justinian Institutes). In the second volume of the Blackstone Commentaries, the *Rights of Things*, there are perplexities regarding accretion and avulsion (Sax 2010). Blackstone confirms accretion by stating, "if this gain be by little and little, by small and imperceptible degrees, it shall go to the owner of the land adjoining". With regard to avulsion, Blackstone states "if the course of the river be changed by a sudden and violent flood, or other hasty means, and thereby a man loses his ground, he shall have what the river has left in any other place, as a recompense for this sudden loss". It would appear Blackstone was allowing for loss and affording the landowner the option of reclaiming the land.

Corkill (2012) stated the Doctrine of Accretion was first used in an Australian court case with *Foster v Wright (1878)*. An influential Australian court case, often cited internationally is

Southern Centre of Theosophy Inc v South Australia (1978 & on appeal 1982). This case accepted a series of accretive changes within the Doctrine and stated that there should not be such a focus alone on the gradual concept, each case should be treated on its merit and circumstances and acknowledges a 'logical, and practical, gap or grey area' between the distinction of accretion and avulsion. In the High Court of Australia, *Hazlett v Presnell (1982)* the findings confirmed the application of accretion and the basis:

> "*at common law, where land is bounded by a navigable river and the rule ad medium filum does not apply, the title to the land is applicable to the land as it may be from time to time changed by the gradual and imperceptible processes of erosion and accretion. This is so even if there be the means of identifying the original bounds of the property (see Williams v. Booth [1910] HCA 12, Southern Centre of Theosophy Inc. v. South Australia (1982) AC 706).*

Corkill (2012) commented on the role of gradual change by citing *Hindson v. Ashby (1896)* where it was argued that one of the tests for gradual change is: it must be imperceptible to the eye from day to day. With the frequency and high resolution that satellites capture aerial imagery, it is likely to put an end to the perceptibility test of a gradual determination, resulting in the majority of determinations being found as avulsion (Corkill 2012).

The *SMI Act 2003* defines accretion as "the change to the location at law of a boundary, having regard to any shift or modification over time of the feature constituting the boundary, by gradual and imperceptible degrees". Boundary location change is primarily the result of either accretion (gradual build-up of sediment) or erosion (gradual removal of sediment) of the banks of the watercourse, occurring naturally and slowly over time. Avulsion is defined as "the absence of change to the location at law of a boundary, having regard to any shift or modification of the feature constituting the boundary that is not gradual and imperceptible, including, for example, a shift or modification caused by a flood or storm or another rapidly occurring natural process, or by substantial modification of land through human activity" (*SMI Act 2003*). As per the *SMI Act 2003* (Sections 110 & 108), despite where the physical feature boundary currently is, if the change was not gradual and imperceptible, the authoritative location at law of the boundary does not change from a previous registered survey prior to the FNPOS. When the boundary has been determined as undergoing avulsion, the boundary does not move and remains as it was prior to the FNPOS. If the event is avulsive, sudden and creates a perceptible change - it does not alter the boundary. If *SMI Act* Section 109(4) applies, the surveyor must lodge a FNPOS with a survey report and supporting evidence, after which the Chief Executive (DoR) makes a declaration as to the boundary location.

However, change can be a natural consequence of an artificial human activity (e.g. dredging in a channel that creates ambulatory change), there is considerable ambiguity in determination of whether a boundary change is: natural OR due to artificial human activity; accretive/erosive (slow and gradual) OR subject to avulsion (sudden change) in time.

The distinction between accretion and avulsion has ramifications for area and access, either gaining/losing land area or retaining/losing riparian rights and access to water. With accretion, regardless of either gaining or losing land, riparian rights and access to water is retained. With avulsion (where the boundary does not change), if the physical riparian feature shifts beyond the current legal boundary, riparian rights and access to water may be lost. If the boundaries of a watercourse shift to become an internal watercourse riparian rights and access to water has been retained for one landowner but not the other adjoining landowner. It can be complicated -

if two surveys were done at the same time on opposites sides of a watercourse: Surveyor A states that watercourse changes are avulsion and the legal boundary remains as is; Surveyor B on the other side of the watercourse states that watercourse changes are accretive and the legal boundary shifts with the changed natural feature; creating the possibility of overlapping legal boundaries. Any potential influence of artificial or man-made activity complicates matters even further. This conundrum is addressed by Section 17 'Resolving inconsistencies between plans of survey' of the *SMI Act 2003*. Provisions exist for title amendment for physical feature boundaries regarding the surrender or reclamation of land under the *Land Act 1994 Qld* (Section 4.13 of Cadastral Survey Requirements 2021) and also for former watercourse land (Section 4.14 of Cadastral Survey Requirements 2021). Table 1 summarises the potential scenario gains and losses for accretion/avulsion events for both land area and water access.

Table 1: Accretion/Avulsion land area and water access gains/loss scenarios where both sides of the river have been surveyed.

	Land area Owner	**Land area Opposite owner**	**Water Access Owner**	**Water Access Opposite owner**	**Physical description**
Accretion (imperceptible, slow and gradual)	Gain	Gain	Yes	Yes	Channel narrows
	Gain	Loss	Yes	Yes	Channel movement
	Loss	Gain	Yes	Yes	Channel movement
	Loss	Loss	Yes	Yes	Channel widens
Avulsion (both banks significantly affected)	Same (boundary does not move)	Same (boundary does not move)	Yes	No	Channel movement
	Same (boundary does not move)	Same (boundary does not move)	No	Yes	Channel movement
	Same (boundary does not move)	Same (boundary does not move)	No	No	Channel narrows
	Same (boundary does not move)	Same (boundary does not move)	Yes	Yes	Channel widens

There are historical examples in Australia where there have been successful changes to the Doctrine of Accretion. In NSW 2003, the *Coastal Protection Act* was modified and changes provide evidence that the statutes and implementations by the courts can be amended if there is a need (Watson & Harcombe 2005). The modifications to the *Act* stated that neither a Court nor legislative body could increase land area in Coastal Zones from accretion, if it was not sustainable (Section 55N of the *Act*). Sax (2010) suggested there should be changes to the Doctrine of Accretion, by allowing the boundary to follow the natural feature regardless of the "rate, perceptibility, or suddenness of the movement", with three (relevant) exceptions:

1. Where the river shifts to a wholly new channel by cutting across a former oxbow
2. Where movement is caused or increased by landowner or government intervention
3. Where movement occurs over a short period of time e.g. receding floodwaters.

Songberg (2016) suggests that the boundary should follow the natural feature if it moves, claiming that nature does not recognise artificial lines that man has created and that illegal human actions should not alter the boundary. Kwasniak (2013) provides a Canadian perspective, reinforcing the integrity of the Torrens Land title system and the mirror principle, "where a title description provides that a natural boundary… forms part of the title, then changes in that natural boundary could result in changes of entitlement to land".

Ambulatory boundary issues are complex in nature with a number of vested parties including the landowner, adjacent landowners, opposing bank landowners that hold title to land on the opposite side of the watercourse and the state as both registering authority and vested with the rights to water. The parties are concerned with either access to water and/or the land area by location of non-tidal boundaries and the rights to usage or activities that relate to the watercourse. Complexities do not just include boundary determination and also be complicated by private and public ownership, development activity upstream, environmental issues including climate change, native title, water usage issues, illegal filling and contaminated fill, potential public liability through personal injury on land owned of others and boundary dispute.

3. CASE STUDY: ASHGROVE (intersection of Ithaca/Enoggera Creeks, Praed Street)

A case study has been analysed that had riparian change due to avulsion and influenced by man-made activity and the boundary remains in its prior historical location, as per the FNPOS. Historical aerial imagery was sourced through Qld Globe for the case study. The case study has multiple aerial images from 1936 to the present time which were digitised and overlaid so that the top of bank position could be mapped to identify movement through this time period, if any. The aerial imagery has also been assessed for any signs of human intervention such as earthworks, as well as any impacts or changes following major flooding events that may have influence on a determination of avulsion. Cadastral plans were sourced for the case study and the plans were digitised and overlaid with the top of bank position mapped and comparisons made against the aerial imagery. The case study is located near stream gauges that have been collecting data since 1977 and the data was charted to identify flooding events occurring in the catchment to identify any correlation between flooding and ambulatory boundary movement.
The case study focuses on the intersection of Ithaca and Enoggera Creeks, Ashgrove (see Figure 4). Both physical and cadastral boundaries are depicted in Figure 5, the yellow lines being the cadastral boundaries and blue lines the current watercourse top of bank location from Qld Globe and located as per the *SMI Act* (Sect. 100). The watercourse has moved approximately thirty meters in a southeast direction from the 1928 recorded location to its current physical location. The site was determined as experiencing both avulsion and man-made activity. In this instance, the FNPOS survey was commissioned by the owners on the south-eastern side of the creek. The boundary determination, as per current legislation, highlights the issues that can occur regarding ambulatory boundaries, in particular riparian access, avulsion and man-made activity.

Figure 4: Intersection of Ithaca and Enoggera Creeks (https://cityplan.brisbane.qld.gov.au/eplan/property/72RP54128/0/213?_t=property)

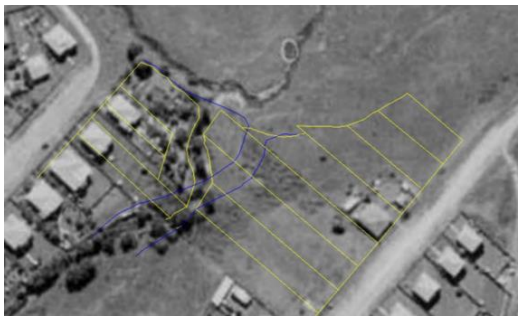

Figure 5: 1936 aerial imagery; current boundaries overlaid in yellow; current top of bank creek location in blue and partial outline of the 'old' creek bed circa 1864 (Qld Globe).

3.1 Case Study Survey History and Analysis

In 1916, Sect. 76 of the Rules and Directions for Guidance of Surveyors (Department of Public Lands) effecting surveys under the *Land Act* (1910) aimed to establish uniformity of practice in the measurement of watercourses. It was directed that measurement be to the edge of the bank limiting the watercourse under normal conditions as indicated by a normal water level or other feature. Guidance for surveyors was confounded by Directions for Guidance of Surveyors (Surveyors Board) effecting surveys under the *Real Property Act* (1877) which did not provide specific guidance and nominated measurement to a watercourse boundary (Sect. 42/44/59). Subsequent guidance was not issued until 1964 Rules and Directions for Guidance of Surveyors (Department of Lands) effecting surveys under the *Land Act* (1962/63), reiterated the 1916 Directions for watercourse measurement. Surveys done prior to 1916 were under the direction of the 1898 Rules and Directions for Guidance of Surveyors (Department of Public Lands) for surveys under the *Land Act* (1897) were directed that measurement is to the top of the bank where they are bold and well defined, which left some interpretation of top of bank locations within the riparian zone. The most recent survey of the ambulatory boundary of the southern bank was in 1928 on RP47708 (field notes not available). The Figure 5 creek 1936 imagery and boundaries matched well, showing the top of bank was adopted as the creek boundary as per Sect. 76 Rules and Directions for Guidance of Surveyors (Department of Public Lands). Survey plans showing the creek boundary in 1864, 1914 and 1928 were overlaid with current aerial imagery (Figure 6) to highlight the ambulatory nature of the creek. The cause of boundary shifts is unclear, however there were several floods around that time, notably in 1893 and 1898. The measurement in 1914 may have been to a higher bank, whereas the 1864 and 1928 plans likely measured to the edge of the bank or channel limiting the watercourse under normal conditions.

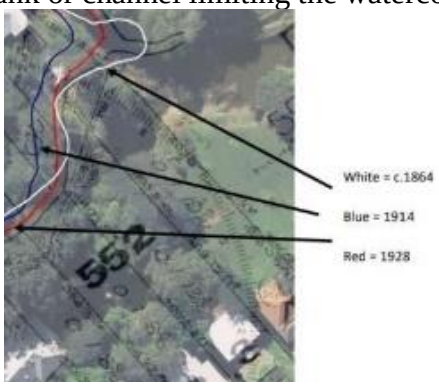

Figure 6: Current aerial imagery with overlay of the northern bank of the surveyed creek positions of 1864, 1914 and 1928 showing the creeks ambulatory nature (Qld Globe).

Figure 7 shows the approximate location of the northern creek bank over time, digitised from aerial imagery, 1914/1928 plans, showing a temporal comparison of the aerial imagery to the 1974 floods. This overlay indicates that the creek continues to move over time since the 1914 determination with the final yellow line showing the creek position, after the 1974 flood event.

Figure 7: Early Survey Plans (blue and red) and subsequent aerial imagery showing physical temporal riparian change of the northern bank of the creeks to 1974 (Qld Globe)

Following the 1974 floods, aerial imagery from 1981 appears to show significant man-made activity including fill on both sides of the creek(s), altering the banks of the creek. The *SP325743 Physical Features Report* confirms "man-made intervention is likely to have taken place to fill in the old creek bed and banks". The *SP325743 Physical Features Report* also confirms that the section of Ithaca Creek in Lots 3 and 4 has taken a new and straighter path bisecting the Lots. Figures 8 and 9 show the position of the watercourse after the 1974 flood and the current south-eastern bank to the cadastral boundary. The *SP325743 Physical Features Report* confirmed the creek has not changed since the 1974 avulsive change.

Figure 8, Current bank position and 1974 flood imagery (SP325743 Physical Features Report).

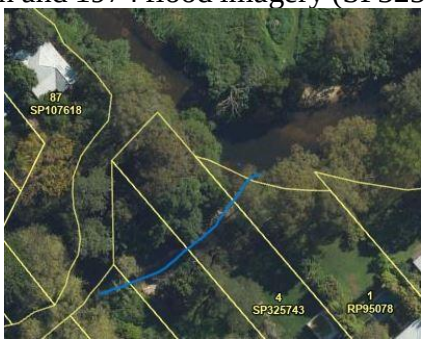

Figure 9: Current cadastral boundary/ physical location of the south-eastern bank(Qld Globe).

The *SP325743 Physical Features Report* stated on-site inspections with the owner (since 1997) of Lot 87 on the north-western bank of the watercourse stating that the previous owner had carried out works to fill and level the 'old' creek area, confirming man-made intervention to the original creek location. Current imagery shows that Lot 87 has significant tree canopy and vegetation coverage which limits the prospect of erosion in a future avulsion event. The creeks at the intersection of Ithaca and Enoggera Creeks have been subject to continual change since its first recorded position and it is understandable to reach a determination that changes may have occurred due to avulsive events and through human intervention. Given the inconsistency of imaged temporal changes (Figure 7) it is difficult to conclude that changes may have occurred incrementally through uneven avulsive cycles with perceptible jumps, as per *Southern Centre of Theosophy Inc v South Australia (1978 & on appeal 1982)*.

Figure 10 shows river height gauge data upstream of the site and flood events since gauge installation in 1972, that may have potentially impacted the ambulatory boundary. It is when the river is in flood that the most intensive transport process occurs and is likely to lead to erosion (Rowinski and Czernuszenko 1998). The red line is the normal level of the watercourse at the Enoggera Creek flood gauge and shows flood events are inconsistent and recurring.

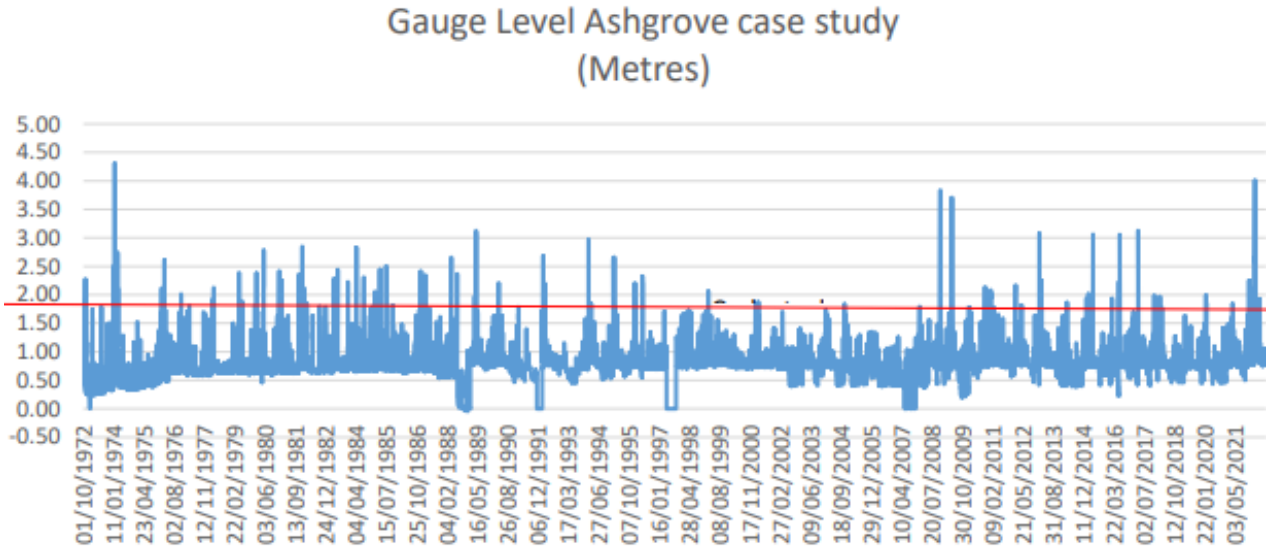

Figure 10: Enoggera Creek flood gauge data since 1972, showing frequency of flow above the ambulatory boundary top of bank elevation (Data: https://water-monitoring.information).

Recent determinations (the same surveyor) reported avulsion changes in 2021 by SP324743 and SP331112. The surveys are re-surveys of Lot 3 and Lot 4 on RP47706, see Figure 11 below. As a result, the boundary at law was compiled from 1928's RP47706 under Section 110 of the *SMI Act* (2003) The resultant impact of determination can be seen in the merged Figure 18 below, which shows Lot 4 extending approximately 20m beyond the physical location of the creek for both side boundaries, Lot 3 is similar for the common Lot 4 side boundary. If the physical location of the bank was used for Lot 3, the land area would be approximately 311 square metres less than determined and Lot 4 would be approximately 457 square meters less. Given the increase and spread of urban development activity in the area since RP47706 in 1928, it is unlikely that the current ambulatory boundary of Lot 4 SP325743 will coincide with the physical location of the watercourse given the current Lot 4 (20 Praed St) creek boundary (see Figure 11) extends up to 17m beyond the Brisbane River flood planning area of the opposite

side of the creek (see Figure 12), affecting riparian access of the landowner on the opposite of the creek. It is difficult to presume in areas of avulsion cycles and man-made activity that a riparian boundary at any single point in time, represents an 'authoritative' location.

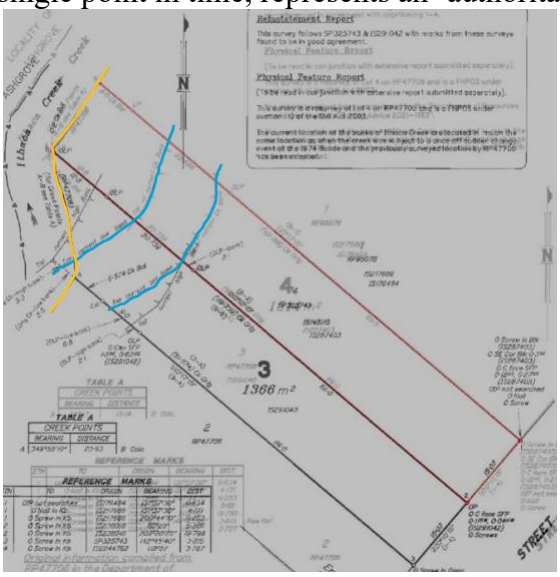

Figure 11: Merged image of two recent SP's where the blue lines are the current physical top of bank position, the yellow line is the FNPOS cadastral boundary.

Figure 12: Brisbane River flood planning area intersection of Ithaca and Enoggera Creeks (https://cityplan.brisbane.qld.gov.au/eplan/property/4SP325743/0/213?_t=property)

4 DISCUSSION/OPTIONS FOR ALTERNATE BOUNDARY DETERMINATION

The case study highlights the need for alternate determinations in ambulatory boundaries to preserve the rights of all landowners. If the change to the ambulatory boundary has permanence and occurred without man-made influence, a landowner should have options available to redefine the boundary in a timely process to address the possibility of permanent avulsive ambulatory change where an owner can lose physical riparian access. There could be an amendment to legislation surrounding the permanency of change in the ambulatory boundary regarding re-determination due to either accretion or avulsion, with certain exceptions e.g. suddenness/man-made intervention. Sax (2010) suggests that "the requirement of gradualness (for a change to be accepted as accretion) stems from the theory based on experience that an increase which is gradual is likely to be permanent", however avulsive change can also have permanency, if it is not subject to a subsequent significant avulsive event. Avulsive change becomes particularly problematic if the physical shift of the watercourse is such that the channel

becomes wholly contained within an existing cadastral land parcel (like 20 Praed St in Figure 12). Step by step change could be considered ambulatory, regardless of whether the change is by accretion or avulsion, again with certain exceptions e.g. man-made activity. Modern surveyors are afforded the luxury of aerial imagery to assist determinations. The courts ruled in *Attorney General v Chambers (1859)* that accretion was acceptable if it was "little by little", despite large change to the boundary. The impact of climate change may result in more frequent and more severe events, creating the likelihood of further change to the physical riparian boundary. If legislation allowed surveyors to assess step by step changes as accretion, it would create a more accurate cadastre by allowing realignment changes to rectify problem areas that have experienced change that have permanence. The option of applying a limitation period for the reclamation of land by a landowner who has 'lost' land in a significant avulsive event is complicated by the possibility that reclamation of land that is confined to a single land parcel may run contrary to changes in the localised catchment and riparian zone.

As a matter of course broader cadastral survey requirements should require measurement to both sides of a watercourse to assist in identifying impacts that may affect littoral/riparian rights and physical riparian access for a landowner (back to the 1964 Directions) and remove the possibility of overlapping cadastral boundaries. Current survey requirements in Queensland do not require measurements to the opposite bank for a riparian boundary survey re-determination. If someone seeks a re-determination, should they be required to assess the extent and impact on adjacent and opposite landowners? Increased cost due to travel and access may be a barrier to implementation and may be cumbersome with larger watercourses (e.g. Brisbane River).

To apply avulsive change to any ambulatory boundary, certain exceptions should be made including: identification of change that has been caused because of sudden change, identifiable human intervention and man-made activity and where changes are transient, such as floodwaters or temporary declines in water levels due to weather cycles. The landowners on the other side of a riparian boundary must be given consideration, especially for smaller watercourses, as there will be a landowner (either the Crown or a private landowner) to avoid the possibility of overlapping cadastral boundaries, especially if the impact is one that deprives riparian rights and access to the physical feature by a landowner on the opposite bank.

5 CONCLUSION

Since Justinian times, accretion has been the rule and avulsion has been the exception. "One naturally searches for a reason or rationale for the requirement that the process be gradual and imperceptible, but this proves elusive." (*Southern Centre of Theosophy Inc. v. State of South Australia 1982*). What is clear is that legal definition will not solve every situation where a real-world scenario exists. "Often change is gradual, but quite perceptible; sometimes change isn't very gradual, but neither is it sudden or violent" (Sax 2010). The common law position of the courts has derived from countries that differ greatly to Australia, where our climate and environment around rivers and creeks are better known for their extreme events, rather than their consistencies (Songberg 2002). The Doctrine has rarely been challenged nor modified to align with modern challenges relating to avulsion. There is a need for laws and regulations to be able to provide for change in ambulatory boundaries that occur naturally, either by accretion or avulsion, and be excepted through human activity, unless it is permanent or incremental change. It is worth considering an update to legislation in Queensland and the Doctrine of Accretion to ensure the rights of all riparian landowners and stakeholders are considered.

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