Tailings Storage Failures: Impact on the industry, design, operation and people

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As predicted by Powel (2000) claims for professional negligence are very common and their frequency is increasing due to the increasing demand for professionals' services, specialisation, higher standards, intolerance of poor performance by societies and the increasing litigious nature of business.

The increasing expectations of the society are reflected in the changing attitude of the authorities and courts towards professionals when things go wrong. The changing attitude is fuelled by the unprecedented media coverage of failures of structures with human and environmental losses. This is particularly relevant to the tailings industry, which is marked by the recent dam failures in Canada, Brazil, Mexico, China, Australia and India.

The far reaching expectations for duty of care of professionals has been strikingly illustrated from the fallouts from recent major and widely publicised TSF failures such as Mt Polley (three consultant engineers accused of unprofessional conduct), the 2015 Samarco failure (22 individuals charged with various criminal offences including homicide) and the recent Brumadinho failure (charges of false representation have also been brought against the consultant engineers).

This paper examines the responsibilities and duties of engineers operating in the tailings industry with respect to the professionals' duty of care and the consequences of breaching those responsibilities and duties.

This paper also discusses the potential conflicting interests of consulting engineers and proposes that engineers are, in the vast majority, ill-prepared for navigating the changing waters of professional negligence.

The authors of this paper believe that a better understanding of the professional duty of care could reduce the number of claims for professional negligence. As a corollary, the reduced rate of professional negligence could result into fewer tailings failures in the future.

Professional industry bodies such as Engineers Australia should act to clarify the legal obligations and duties of engineers, as they are the best placed institutions to do so for the whole industry. In addition, consideration should be given to inclusion of a discussion of the aforementioned obligations and duties into relevant ANCOLD Guidelines.

TSF failures and responses

Recent failures of tailings storage facilities (TSFs) have immeasurably impacted the tailings industry from the regulatory, design, operation and management perspectives and the way the duty of care is understood by different parties. These changes are results of the definite and very real impacts that these failures have had on the downstream environment and populations, but also as a result of other issues, such as the public perception of TSFs and the mining industry in general, which has been heavily influenced by the media.

Various industry bodies and organisations maintain readily available registers of Tailings Storage Facilities (TSF) failures, including ICOLD (ICOLD, 2011), the World Information Service on Energy (WISE, 2019) Uranium Project and the World Mine Tailings Failures organisation (WMTF, 2019). This paper will not replicate these registers, rather draw on pertinent facts arising from these registers.

The striking feature when reviewing TSF failures over any given period of time is the similar rate of large TSF failures; between two and five occurrences per year. Of concern is the fact that a similar rate of failures was reported by ICOLD in 2001 (ICOLD, 2001). Given that almost 20 years has passed since the publication of that bulletin, it is concerning to see that as an industry we have been unable to lower the failure rate.

TSF failures in the last ten years have occurred in a multitude of countries, occurred in operations managed by both large and small mining operators and failed for a variety of reasons. Given the lack of pattern associated with the failures in the last 10 years, it is difficult to discern a single issue leading to these failures and therefore as an industry, address these failures simply and efficiently. This was reflected in Morgenstern's 2018 lecture (Morgenstern, 2018), which stated "*No set of simple prescriptions will resolve the crisis (of continual TSF failures).*" At the other end of the spectrum, Herza et al. (2019) concluded that a systematic failure to recognise the potential geotechnical hazards, their consequences and the trigger mechanisms are the underlying reasons for recent failures of large tailings dams. In addition, it could be argued that

the recent failures are a result of systematic issues with management of mining companies and their inability or unwillingness to act when clear warnings are provided. Regardless, these reasons point to failures being directly associated with the performance of the individual parties involved and the design engineer, in particular.

Given the varied locations of failures, it is interesting to note that, generally, news articles pertaining to TSF failures in the last five years have focussed mainly on the Mt Polley (2014), Cadia (2018) and Brazilian failures (2015 and 2019). For example, conducting a news article search (in English) regarding a TSF failure in Jharkhand, India at the Hindalco Alumina operations on the 9 April 2019 yields an order of magnitude smaller amount of results than the January 2019 Brumadinho failure (6,270 compared to 54,500). While no means a comprehensive or definitive measure of the media coverage of each failure, this is arguably a proxy of the interest in an event and the availability of information available to the general public.

Reviewing the mechanics of how, and which, TSF failures are reported to the general public is outside the scope of this paper. However, it is reasonable to conclude that public perception of TSF failures shapes society's attitude towards and demand on the involved engineers and other professionals.

As a result of the tailings failures in the last five years there have been numerous calls for change to the tailings industry and subsequent changes as a result for these calls. Examining each of these impacts and predicting the resulting changes to the tailings industry would require a comprehensive review. However, it is obvious that the recent failures have already resulted in large changes to the tailings industry, with indications that changes will only continue.

One of these impacts to the tailings industry, which is focal point of this paper, is the resulting legal charges of those not directly involved with the operation or management of the failed TSFs but who carried out design and/or reviews, which includes visual inspections and technical reviews of various aspects of a TSF.

For example, in the aftermath of the 2015 Fundao Brazilian failure VOGBR Consultancy and its senior engineer was accused of presenting a false report on the stability of the dam embankment and was found guilty of deliberate misconduct after a seven month investigation (Mining Technology, 2018). The findings have led to criminal proceeding, including possible murder charges.

Similarly, subsequent to the 2019 Brumadinho failure, consultant engineers from TUV SUD who had carried out the latest stability assessment of the dam embankment and attested to its stability were arrested (Phillips, 2019). Charges of false representation have also been brought against the consultant engineers (DiChristopher, 2019).

Another example can be found in one of the outcomes from the Mt Polley failure. Disciplinary hearings (that had not yet been held at the time of writing) that will be overseen by British Columbia's engineering regulatory body have claimed that three engineers were negligent and exhibited unprofessional conduct (Woo, 2018). One of the three engineers has been accused of unprofessional conduct due to accepting the role of engineer and accepting the design of the facility while being unqualified to do so. In addition, a senior engineer has also been accused of unprofessional conduct by allowing the previously mentioned engineer to accept the position. Other allegations against the senior engineer include failing to appoint a suitably qualified geotechnical engineer to assess unfilled excavations.

There is no doubt that outcome of these hearings will have repercussions on the tailings industry and the recognition of the potential for findings of negligence against design engineers in the tailings industry. The examples of charges being levelled against engineers who carried out design and reviews of TSFs which subsequently failed introduces questions regarding an engineer's perceived and actual duty of care and the liability attached to carrying out design or review work. One could argue that between the time of the inspection of these TSFs and failure, a multitude of factors could have results in the failure of the TSF, which may not have been present at the time of the inspection.

Regardless, the authorities evidently believed that these engineers did not carry out their work to an acceptable standard which, at a minimum, meant that they were partly responsible for the failure of the TSFs and the resulting consequences to the downstream communities and environment.

Because engineers are not commonly trained in civil and criminal law matters and given the highly litigious nature of the professional environment today, it is imperative that design engineers associated with TSFs are at least aware of the duty of care that is expected of them, merely as a result of undertaking work associated with said TSFs.

Changing coastline of negligence

Legal liabilities

As discussed earlier, people involved in TSFs in various capacities open themselves to legal liabilities. The reasoning in charging executives and directors within the companies that own and operate TSFs, who are recognised to be the ultimate decision makers, may be understood. In contrast, the type of charges, along with the associated potential sentences, directed against individual engineers who carried out design and review services was likely more alarming, especially for engineers who carry out these services as part of their routine work.

It should be noted that while the scope of "review services" can be quite varied and extensive, for the purposes of the discussion presented below, it has been assumed to mean the review and verification of design and dam safety issues and as such extends to annual review services, independent review boards and third-party design reviews, as well as Engineers of Record. Hereafter, an engineer engaged in such services had been termed a design engineer.

Most design engineers likely understand that, should they do an inadequate job in regard to time, cost or quality, there will be ramifications. However, these ramifications are often thought of in the realm of limiting claims from their clients, damage to their and their company's reputation and the resultant decrease in repeat work from their client. These ramifications are often deemed to be limited to the commercial liability and impacts.

As an example for a TSF raise design, suppose it has been identified by the design team that there was inadequate information in regards to a potentially problematic zone of foundation materials. Almost certainly, the main consideration for the design team at that time would be how to address the issue with insufficient information, while limiting unwanted commercial implications for themselves and their client.

The long-term legal liability and potential criminal charges that the design team will have opened themselves to, should a TSF safety issue eventuate as a result of the design not successfully addressing the problematic foundations could be down the list of immediate considerations on the designers' minds.

However, should such a safety issue eventuate, it is almost certain that members of the design team would be legally implicated, as evidenced by the real-world examples presented earlier. The issue for the design team is in the instance where they believe that they have taken appropriate measures in addressing the design issue with considerations to uncertainties, whereas a court of law may view this differently, based on the concepts of professionals and professional duty of care to downstream populations and environments. This extends further to duty to warn in the instances of technical review work, or similar.

This gap of understanding of the legal concepts for design engineers can be argued to be due to pure unawareness together with a commercially focused decision making progress, as opposed to wilful ignorance. This is evidenced by design engineers often having to deal with some legal concepts such as limits of liabilities and professional indemnity insurance. By and large, design engineers can go their whole careers without ever being taught or briefed on their legal obligations to their clients and third-parties exposed to risks as a result of their work.

This gap of understanding could also be argued to be due to, and exacerbated by, the fact that technical design and review work of TSFs is not regulated in many locations. Whereas owners (and by extension, engineers in their employ) have regulations, licence conditions and internal guidelines dictating how they should operate, design engineers often have no such direction.

Before the considerations of an engineer's duty of care and duty to warn are further explored, three considerations should be discussed and acknowledged.

Firstly, the discussion presented in this paper hinges on the assumption that investigation, design and review activities carried out by design engineers are imperative to the safety of the TSF. Investigation and design activities are required to identify considerations related to the in-situ conditions, selected TSF arrangement, construction materials, construction techniques, ongoing operation and how best to address these considerations in such a way that results in minimising the likelihood of failure of the TSF and resulting impacts. In addition, technical reviews of TSFs are undertaken to determine if the facility is being operated as assumed and that various parameters are within limits assumed during the design. Under these circumstances, the quality of design and review activities directly impacts (lowers) the likelihood of failure of a TSF, and therefore relates the work that design engineers perform to the downstream populations, which would be affected by the TSF failure.

Secondly, the discussion presented draws on legal concepts and examples from various countries, states, districts and legal jurisdictions, where it is recognised that laws and legal conventions vary. In addition, cases of liability outside the confines of dam failures are also reviewed. Binder (2002) states *"… even though legal principles may vary by jurisdiction, principles of engineering apply universally"* and *"regardless of jurisdiction, should a dam failure result in loss of life, personal injury or substantial property damage, it is fairly certain that most jurisdictions will fashion a means to compensate the victims."* As such, reviewing professional duty of care principles from around the world will still illuminate TSF design engineers everywhere about their duty of care.

The third consideration is the legal concept of Acts of God. In regards to TSFs, Acts of God are a legal defence that states that a failure was a result of an eventuality outside human contemplation and influence (Binder, 2002). An example of this would be a catastrophic storm or an earthquake event. The basis of this defence is that regardless of the alleged negligence, the consequences of failure would have happened regardless due to the magnitude of the extreme event. The review of professional duty of care and negligence in regard to Acts of God are outside the scope of this paper.

To refocus and reiterate, the review a design engineer's duty of care to third-parties including downstream populations and the environment should be a concern before this type of work is undertaken. In addition, the legal elements required to prove that duty of care has been breached and that the breach has caused loss or harm to third parties, resulting in a finding of negligence against the design engineer are also of concern which must be understood by the people (engineers) that is pertains to.

Forms of professional negligence

In the legal context, two forms of negligence rulings exist, these being negligence at tort and criminal negligence.

Negligence **at tort**, or civil negligence, involves comparing the conduct of the defendant against a standard duty of care, potentially resulting in the **need for compensation to the person affected** (based on the elements of the cause of action being met). In comparison, a finding of **criminal negligence** requires falling short of the required standard of care to a much greater extent. For example, a finding of criminal negligence in the UK requires a breach of a duty of care while exhibiting a **disregard for the life and safety of others** as to amount to a **crime, deserving punishment** (Macfarlane 1998). As indicated in *R v Batemen* (Macfarlane 1998) for criminal negligence:

> *"…in the opinion of the jury, the negligence of the accused went beyond mere matter of compensation between subjects and showed such disregard for the life and safety of others as to amount to a crime against the State and conduct deserving punishment."*

Similarly, in Australia, for a successful finding of manslaughter by criminal negligence, there must not only be a breach of duty resulting in death, but the breach must occur"... in circumstances which involved such a great falling short of the standard of care which a reasonable man would have exercised and which involved such a high risk that death or grievous bodily harm would follow..." (*Nydam v R* [1977] VR 430).

Both forms of negligence are a result of a person failing to meet the duty of care required of them, however, one of the defining characteristics between the two forms of negligence is the severity of the breach.

The differing standard of proof required to prove negligence at tort and criminal negligence must also be considered.

In criminal matters, the standard of proof required for a positive finding of guilt is 'beyond a reasonable doubt'. However, the standard of proof in civil matters, such as negligence at tort, is on the balance of probabilities. The requisite standard to prove criminal negligence is therefore higher than the standard to prove negligence at tort. This could result in a situation where the same breach of the duty of care leads to a finding of fault in the civil sphere but does not lead to a finding of criminal guilt.

For design engineers to ensure that they do not satisfy the elements required for a finding of negligence (both civil and criminal), they require an understanding of the duty of care imposed on and expected of them.

Who is a professional

Intrinsic to the concept of professional duty of care is the definition of a professional, which previously in the late 19th and early 20th century was more related to select professions, that is, what one did. Over time, the concept of a professional has expanded and morphed to a nebulous term that indicates one has trained and studied in a field sufficiently to be able to offer services related to that field, that is, what one is (Powell, 2000)

However, as the definition of professional has expanded, so to have society's expectation of higher standards and intolerance to unwanted incidents as a result of services rendered by a professional, as evidenced by increasing numbers of claims of professional negligence (Powell, 2000).

As a result of these claims, various legal definitions of what constitutes a professional have evolved (Bolam, 1957 (Legal citation: *Bolam v Friern Hospital Management Committee* [1957] 1 WLR 582); Martin, 2011; Charret et al., 2013). However, these definitions have similar components and a professional is understood to be someone who:

- Possesses and utilises skill and understanding of their profession on level with an ordinary member of that profession
- Is aware of advances in knowledge, technologies and discoveries in their profession
- Is aware of their (the individual) deficiencies in knowledge and skill in regards to their profession
- Is aware of the hazards and risks in carrying out their profession to the extent that an ordinary member of that profession would be

As demonstrated by the points above to be a professional is to be ordinary in one's field. This is arguably not a high bar to exceed and, as a corollary, would be difficult for almost every design engineer to claim to not be a professional. This definition of a professional will be discussed in context of duty of care and standard of care later on. It should also be noted that in many countries, such as America and Canada, a professional engineer is also required to be registered as such in their local jurisdiction. This is not a requirement in Australia, except for Queensland.

Duty of care

Various duties of care are imposed on design engineers when they provide professional services. Contracts and other forms of engagement of design engineers by clients commonly include the duty the design engineer has to the client. These contractual duties are related to the design engineers' performance, the outcomes of the activities and other contract specific aspects and these are likely to be understood by the design engineer. Even if the minutiae of the contract terms and conditions are not understood, at a high level, engineers understand that poor performance could lead to claims from the client, unsatisfied clients and lack of repeat work.

However, there are additional duties of care imposed on the design engineer by common law and statute, understanding of which may be beyond the design engineers' training and experience. Yet, these non-contractual duties of care may have larger personal implications for the design engineer than the contractual duties to the client.

In general, a professional duty of care exists between design engineers and anyone who may be impacted as a result of services rendered by the design engineer. For the context of TSFs, this would include anyone who would be impacted directly or indirectly by the TSF failure.

The means of establishing that one party owes a duty of care to another party differs across countries and legal jurisdictions. In the UK, if a previous case cannot be used to establish the existence of a duty of care then the following criteria must be met before a duty of care can be established (Caparo v Dickman, 1990 (Legal citation: *Caparo v Dickman* [1990] UKHL 2; [1990] ALL ER 568, [1990] 2 AC 605)):

- Harm must be a reasonably foreseeable result of the defendant's conduct
- A relationship of proximity must exist between the defendant and the claimant, that is the result of the act (or non-action) of the defendant must be shown to have affected or can be shown to cause an effect on the person affected (proximity criteria)
- It must be fair, just and reasonable to impose liability on the defendant

In Australia, there are various tests to determine if duty of care is owned from one party to another. For cases where the impacts on the plaintiff are purely economic, and there is no statutory or case law which establishes whether a duty of care does or does not exist, the Court applies a "salient features" test, where some of the following are considered by the Court (Perre v Apand, 1999 (Legal citation: *Perre v Apand* [1999] HCA 36; 198 CLR 180)):

- Whether imposition of a duty of care would lead to 'indeterminate liability', that is would imposing a duty of care on an individual interfere with their social or business interests
- Whether imposition of a duty constitutes an unreasonable burden on individual autonomy
- The degree of vulnerability of the plaintiff to the defendant's actions, that is would the person affected be able to guard themselves from the consequence of the defendant's actions. This is similar in intent to the proximity criteria established in English Law
- The degree of knowledge which the defendant had about the probability and likely magnitude of harm to the plaintiff

The above conditions imply that duty of care is owned from design engineers to the third-parties including downstream populations, especially when considering the assumption made earlier that the activities design engineers carry out directly impact the likelihood of the TSF failures.

The first two points detail the impacts of imposing a duty of care on design engineers. It is recognised legally and within the engineering field that design and review services should be executed with consideration for the people who could be impacted as a result of the provided services. Evidence of this can be seen in statements included in Engineers Australia *Our Code of Ethics* (EA, 2018) as well as the consequence based design approach outlined in the various ANCOLD Guidelines, in particular the *Guidelines on the Consequence Categories for Dams* (ANCOLD, 2012). Indeed if the duty of care on design engineers is to not create unduly high risks to downstream populations and environments, carrying out our work in accordance to regulations, conditions and standards (which is expected of professionals) results in these two points being met.

For the third point, it is impractical to assume that any downstream populations could limit the consequence of a TSF failure to themselves or to the environment. Should the failure be attributed to flaws in the design or review carried out by a design engineer, then any affected downstream population would be, at least partially, vulnerable to the actions or lack thereof of the design engineer. Arguably, once failure of a TSF is imminent, the only actions that could mitigate consequences to downstream populations are stipulated in a facilities' Safety Emergency Plan, or similar, which the design engineer should participate in developing and reviewing. This, if anything, increases the extent of vulnerability of downstream populations.

The fourth point of engineers understanding the probability and magnitude of impact as a result of TSF failures is likely the easiest to deem applicable. As risk based design and management has become widely accepted in the tailing industry, it would be almost unbelievable that design and review work associated with TSFs be carried out without at least a qualitative risk review. In addition, it could easily be argued that there is no one better to understand the risks of associated with a given TSF than the design engineer.

The points above refer to imposing a duty of care on design engineers to where the impacts of a TSF failure are purely economic. However, consequences of TSF failures are rarely limited to pure economic loss and include loss of tangible assets and life. For cases where impacts extend beyond pure economic loss, common law has usually **treated knowledge or reasonable foresight of harm as enough to impose a duty of care** (Perre v Apand, 1999 (Legal citation: *Perre v Apand* [1999] HCA 36; 198 CLR 180)).

As seen the above points, applying a duty of care on design engineers to populations and the environment downstream is not an onerous task and is even expected from industry bodies such as Engineers Australia and the conditions of applying a duty of care are often achieved due to the regulations, licence conditions and standards that are worked to.

Breach of duty of care

With an understanding of negligence, duty of care and a the definition of a professional, the next step is outlining the elements that need to be established for a court to make a finding of negligence in respect of a breach of a duty of care by an engineer.

Simply put negligence occurs when it is determined that a person (design engineer) has not acted in a manner that would be expected of a professional in their field (including taking precautionary and reactive action), resulting in loss or harm to people who they have a duty of care towards (Charrett et. al., 2013).

Thus, a finding of negligence requires a failure to act in accordance with the standard expected of a professional within their field.

As stated earlier, a professional is to be an ordinary practitioner in one's field. To expand further:

"... a professional ... should command the corpus of knowledge which forms part of the professional equipment of the ordinary member of the profession. (They) should not lag behind assiduous and intelligent members of (their) profession in knowledge of new advances, discoveries and developments in (their) field. (They) should have such awareness as an ordinarily competent practitioner would have of the deficiencies in (their) knowledge and the limitations of (their) skills. (They) should be alert to the hazards and risks inherent in any profession or task (they) undertake to the extent that any other ordinarily competent members of (their) profession would be alert. (They) must bring to any professional task (they) undertake no less expertise, skill and care than other ordinarily competent professional would being, but need bring no more. The standard is that of the reasonably average. (*Eckersley v Binnie & Partners* [1988] 18 Con LR 44, CA).

The above statement outlines the expected standard of care from a professional in any given profession. As the minimum expected level of competency, the actual conduct of a professional is measured against the standard of care expected from a professional to determine if one has breached their duty of care in carrying out their work.

A professional is not negligent in providing a professional service if it is established that the professional acted in a manner that (at the time the service was provided) was widely accepted as reasonable. In consideration of the reasonableness of how a professional acted, courts will consider the opinion of respected practitioners in the field and take into account differing opinions of practitioners within the field (Charrett et al., 2013) (NSW, 2002).

Analysing and unpacking the quote above highlights important considerations regarding the standard of care expected of design engineers that said engineers should be aware of, as well as the conditions that result in them being liable for negligence.

Firstly, it is imperative that engineers are aware of current practices. This includes standards, guidelines and methods of investigations, analysis, construction and operation of TSFs. Following from this, it is not enough for engineers to claim ignorance of current practice as a defence against negligence. Thus, it is crucial for engineers to take it upon themselves to be conscious of developments in the field of the engineering with attention to concepts applicable to dam investigation, design, construction and ongoing monitoring.

Secondly, and as a corollary of the first point, an engineer's fulfilment of their duty of care can only be reviewed in context of the time that the work was being undertaken. It is not reasonable to assess an engineer's work or actions previous work against current practice, which may not have been current practice at the time the action was undertaken.

Thirdly, the quote above states that a professional (engineer) should be aware of their limitations in carrying out their profession. This means that it is not expected that any one design engineer should be completely knowledgeable on every aspect of engineering associated with dams. This quote results in the recognition that there is no expectation legally that a professional should undertake every aspect of a design or review and instead, may depend on specialists.

Indeed undertaking work outside of one's limitations opens oneself to breaching their duty of care. An example of this can be seen in the decision of the British Columbia Supreme Court in *Lovely* v *Kamloops (City)* (Martin, 2011) where an engineering firm with no experience in waste water transfer stations completed a design of such a station. A lack of fall protection led to two serious accidents involving members of the public. It was decided by the Courts that the engineering firm was partly liable for the injuries.

It was argued by the firm that they had designed the station in accordance to regulations which did not require the installation of guardrails. However, the Court determined that as professional engineers, they should have identified that the regulation was only applicable to worker safety and did not extend to public safety. By not identifying the need to address the public's safety, it was determined that the firm had not acted to the level of standard of care expected of a design engineer in that field and therefore breached their duty of care.

This example shows that the standard of care applied to engineers is independent of their actual level, or lack of, experience and limitations.

It is common belief that regulations and standards are legally required to be followed whereas guidelines are documents that provide guidance regarding current practice for various topics. However, *Lovely* v *Kamloops (City)* (Martin, 2011) showed that in regards to an engineer's standard of care, there is no legal differentiation between regulations, standards

and guidelines. This stems from the requirement for the Court to consider current practice, including commonly accepted industry guidelines, when considering the standard of care that was owed.

However, in being a professional engineer, one has to identify when abiding by guidelines and standards is not sufficient fulfilling one's duty of care. In *Lovely v Kamloops (City)* (Martin, 2011), the design firm believed it had fulfilled their duty of care by following design regulations, however, it was determined that it was negligent in its duty of care to the public.

Another example highlighting this can be found in *BHP Coal Pty Ltd & Ors v O&K Orenstein & Koppel AG* [2008] QSC 141. In this case, a Bucket Wheel Excavator in a mine in Central Queensland had collapsed. Repairs were designed and carried out under supervision of O&K who also inspected the structure bi-annually. However the Bucket Wheel Excavator collapsed again in 2000. It was determined that O&K had breached their duty of care, due to carrying out the design of the repairs in accordance with a guideline which had a new revision being published imminently. It was determined by the court that a reasonable engineer would have doubted the reliability of the soon-to-be-superseded guideline and referred to the new draft guideline which included provisions for dynamic loads.

These examples demonstrate that following standards may not be sufficient to fulfil one's duty of care, meaning that going above and beyond what is dictated in standards and guidelines may be prudent.

In the dams industry, this is reinforced by the fact that guidelines and standards do not exist for various issues due to the technically demanding nature of the issues, such as static liquefaction. Static liquefaction has been identified as the potential cause of failure for the two failures in Brazil that occurred in 2015 (Morgenstern et al, 2016) and 2019 (Nogueira, 2019).

Currently, it is accepted within the dams industry that the conditions, causes and triggers of static liquefaction are not well understood and there is no industry-wide consensus on assessing the potential for static liquefaction, especially in regards to processed materials such as tailings. As a result, it would not be hard to argue that a comprehensive assessment of static liquefaction triggers is outside of the realm of the majority of dam engineers.

If, in review of a TSF, it is identified that there may be the potential for static liquefaction to occur, one has to consider how best to assess the potential static liquefaction and the implications it has on the stability of the dam. Even further, one has to consider if the best course of action is to engage a specialist in the field of static liquefaction to assist in the assessment of static liquefaction in accordance with fulfilling the duty of care to their client and downstream populations. Thus it is important that design engineers truly understands their limitations and limitations of reference materials and the impact that has on fulfilling their duty of care.

In contrast to the concept above where an engineer may have information that they may not be suitably appropriate to assess, a design engineer could find themselves in the situation where there is a lack information, such as insufficient information on material properties or as-constructed information, to use as a basis for design or review work. In cases where continuing the work without further investigation or using appropriately conservative techniques could result in intolerable risk, and potentially breach their duty of care to external stakeholders, the design engineer must be able to agree on a suitable solution to the issue with the responsible stakeholder (i.e. the client or owner).

However, in the case where the design engineer and client are not able to agree on a way forward with regards on how to deal with this insufficient information, the design engineer must decide on how they should responsibly respond, even considering discontinuing the work they were engaged to do, or reporting the issue to regulators, if appropriate. To be sure, these considerations are not made lightly, with the various commercial and legal implications to be considered in the design engineers decision.

It is obvious then that fulfilling one's duty of care may not always be straight forward or easy and may not be in alignment with the commercial drivers of consulting or similar work. As the ultimate defence, one would therefore be prudent in determining the likelihood of breaching a duty of care prior to agreeing to undertake the work, to the maximum degree possible, such as when preparing an offer to undertake the work. In addition, from the above example, it can be seen that a response to potentially breaching a duty of care cannot be prescribed. In one instance, it may be appropriate to decide to discontinue work with a client if the risks to stakeholders are large and the likelihood of breaching a duty of case is high, and in another instance it would be an inappropriate and extreme response. As no two cases could ever be the same, with varying nuances, then no response to two cases could be the same.

Finally, a consideration parallel to duty of care, but no less important in the conversation of professional negligence, is an engineer's duty to warn of risk. This duty is pertinent to design engineers as generally they are the first to identify risks in relation to failure of TSFs, leading to uncontrolled release of stored materials and the associated consequences of said release.

The Civil Liability Acts of the various Australian states have reference to a duty to warn of risk, however, these clauses are not as explicit as clauses related to duty of care. For example, the NSW Civil Liability Act (NSW, 2002) includes:

Clause 5H No proactive duty to warn of obvious risk

(1) A person ("the defendant") does not owe a duty of care to another person ("the plaintiff") to warn of an obvious risk to the plaintiff.

(2) This section does not apply if:

(a) the plaintiff has requested advice or information about the risk from the defendant, or

(b) the defendant is required by a written law to warn the plaintiff of the risk, or

(c) the defendant is a professional and the risk is a risk of the death of or personal injury to the plaintiff from the provision of a professional service by the defendant.

The use of "obvious risks" in the clause above refers to risks that should be obvious to people exposed to the risk. In the context of the risks presented by a TSF, it may not be obvious to downstream populations the magnitude or likelihood of the risks they are exposed to, calling into question whether it could be classified as an obvious risk..

Of course, while downstream populations may have a general sense that any retaining structure exhibits a risk, it is arguable that the average person would have little or no understanding of the concepts of internal erosion or liquefaction and the associated risks. Given that design engineers often discuss risks in relation to failure mechanisms based on geotechnical principles with miniscule order of magnitude, it could be easily reasoned that the risk presented by a TSF is not an obvious risk to downstream populations.

In addition, taking the definition of risk being a product of likelihood and consequence, the general population would not be expected to be aware of the likelihoods which are associated with failure mechanisms, which are often discussed in order of magnitude of 1:1,000 or smaller.

It is easily established that the risks presented by a TSF are not, in any way, obvious to the people exposed to the risk. As a result, the duty to warn of a risk is easily established.

Where ambiguity exists is where an engineer involved in a technical review of a TSF identifies that a TSF is in imminent risk of failure, as rendering audit services does not introduce a risk However, this ambiguity may be resolved in the wake of the fallout from the 2019 TSF failure in Brumadinho. The engineers who completed the audit of the TSF and gave it a clean bill of health were arrested and will potentially be charged with criminal negligence, given the loss of life.

This indicates that prosecutors may view the knowledge of risks of TSF failures being realised and no action being taken to warn potentially affected individuals, especially where loss of life is possible, as criminal negligence. The subsequent result is that, where identified, risk of TSF failure that has the very real possibility of being realised should be communicated to owners of facilities, with additional action to be carried out by the design engineer to ensure that people who could be affected by failure of the TSF are made aware of the risk. This additional action may include reporting to regulators directly.

It is recognised that the above discussion regarding duty of care and duty to warn and implications that all design engineers should carry out their tasks diligently and act as expected of them at all times does not take into real world pressures. As stated previously, liabilities considered by design engineers on a day to day business can be commercially focussed, such as limiting claims for the client and their own company, as well loss of future work should they fail to meet the expectation of the clients. It would be fair to say that this pressure could lead to work being carried out that may contravene one's duty of care or duty to act.

However, as a design engineer in today's litigious environment, an engineer has to be at least aware and consider their actions in regards to their duty of care, even when it flies in the face of pleasing the client, at least in the short-term context of a single project.

Take the example of a design engineer who is completing an independent audit for a TSF at an operational mine and identifies and believes that conditions exist within the TSF embankment that raise the risk of failure beyond acceptable levels. Based on the discussion of duty to warn from above, their first action may be to raise the issue with the client, recommend that populations downstream be relocated until the issue is addressed and seek that appropriate actions are taken.

This recommendation however, could sour the design engineer's relationship with the client who views the recommendation as conservative and could potentially impact the client financially and production wise. Impacts may be as far reaching as lowering safety indices of the company, which could further impact their business in indirect and intangible ways. It could also lead to the reviewer's firm not receiving further work from the client and thus compromise future earnings. In this case the design engineer is in a conflict of interest situation where the commercial objectives of the firm stand against fulfilling the duty of care and duty to warn that the design engineer owes to the population at risk.

The design engineer may agree to ease the recommendation under the commercial pressure applied explicitly or otherwise by the client and the firm and accept monitoring of the site conditions as an interim measure. The design engineer may also choose to simply report the issue without any specific recommendation and course of action. However, should failure of the TSF then occur, the design engineer and client could then be found to be negligible, both in the civil and criminal sense.

The design engineers must therefore weigh their actions against their expected standard of care for them to be completely comfortable that they do not breach their non-contractual duties of care.

While this idealised example simplifies many other considerations, it clearly illustrates that often fulfilling one's duty of care is not a simple task. However, it should be at the forefront of each engineer's mind and direct their actions as best as can be done given the context and situation that they are operating in and at the end of each project, the engineer must be

able to assure themselves that they have complied with their duty of care. At the end of the day, commercial considerations should always be tempered with consideration to technical risk considerations and the engineer's duty of care.

Are we prepared?

Given the legal frameworks in place, the legal fallout from recent TSF failures, the increased scrutiny from all corners on the tailings industry and the unchanged rate of TSF failures, it is not unreasonable to expect that cases of design engineers being charged with negligence will be a feature of the tailings industry going forward.

Design and review work in relation to tailings storage containment is a high risk engineering pursuit as a result of the consequences that are posed should these TSFs fail. This is evidenced by the high premium insurance category that TSFs sit in for mining companies. Given the high risk inherent in design and review work and the unchanged rate of major tailings failures, informing engineers of their duty of care and the implications of failing this duty may dissuade unprepared engineers from performing high risk tasks or undertaking work based on incomplete information, thus lowering the risk of failures over time.

Worryingly however, is the disparity between what design engineers are actually legally liable for and their awareness regarding their legal liability.

This lack of awareness is likely due to the large majority of design engineers not having been formally instructed on commercial and criminal law and the resulting legal implications these have on themselves as a professionals. In addition, once in the workforce, legal training for design engineers is often limited to commercial liability and the impacts it has on a business level.

The issue exists due to the fact that ignorance is not a defence against negligence. That is not to say that design engineers are completely ignorant to the fact that they have a duty to their employer, clients and society as a whole to carry out their jobs to the best of their ability. As stated above, there are very real implications on one's employment should they continually carry out their duty at a substandard level. In addition, various industry bodies have "Codes of Ethics" or similar outlining the values and principles that these bodies believe an engineer should conduct themselves when carrying out their profession.

Examples of this include Engineers Australia (EA) and the Australasian Institute of Mining and Metallurgy (AusIMM). Both bodies have a Code of Ethics (EA, 2018) (AusIMM, 2007) which include phrases such as "*Maintain and develop knowledge and skills*", "*… foster the health, safety and wellbeing of the community and environment*" and "*safety, health and welfare of the community shall be the prime responsibility... in the conduct of... professional activities*".

It can be seen that there is an alignment between the intent of these Codes of Ethics and the Liability Acts presented earlier, with recognition that a design engineer should keep up-to-date with current practice and consider the community as a whole in their work. However, it can be argued that not enough clarity is provided and that with no direct reference to legal clauses, these codes lack emphasis to the real-world implication of not considering one's duty of care.

The authors therefore believe that professional bodies such as Engineers Australia should attempt to close the gap in knowledge between what engineers may believe their duty of care and duty to warn are and their actual duty as prescribed by the law. It may also be appropriate to include an introductory course to duty of care and professional negligence in the undergraduate programs for professionals.

Another way to address the gap in knowledge is by regulation of the engineering profession, with the requirements and acts that come along with regulation. With regulation would come Requirements and Acts that would clearly and directly outline the duties one must fulfil should one wish to be a design engineer.

While regulation of the engineering profession, perhaps by industry bodies such as EA, seem quite far from the system currently in place in Australia, it is a common practice in other countries including Canada.

Canadian provinces are responsible for governing engineers and the profession is self-regulated. For example, in the province of Ontario, the regulating body is the Professional Engineers Ontario (PEO). Engineers wanting to be licenced to practice as an engineer in Ontario must pass a Professional Practice Examination which is an exam on ethics, professional practice, engineering law and professional liability. This exam covers an engineer's duty to the public and commitment to ethics as well as knowledge of relevant common, tort, and contract law. Recommended reference texts to be studied in the preparation of this exam include *Law for Professional Engineers, Canadian and Global Insights* (Marston, 2019) which includes examples of tort negligence cases in the engineering field.

Therefore engineers licenced in Ontario are (or at least should be) aware of their legal liability during design and inspections with respect to safeguarding public safety as well as fulfilling contractual obligations (PEO, 2019).

Further, the Professional Engineers Act (PEO, 1990) is the law that allows the PEO to regulate and enforce the profession.

The Act includes clauses and definitions for negligence, duty of care and duty to care that align closely with the definitions that appear in the Australian state liability Acts presented earlier. In addition, the Act includes a clause stating "without fear or favour expose before the proper tribunals unprofessional, dishonest or unethical conduct by any other practitioner". This clause extends the Duty to Act beyond just beyond acting when one identifies an issue that threatens lives, property

or the environment, but also places a Duty to Act should one see another engineer carry out their job in a way that threatens lives, property or the environment.

This duty is reinforced in the PEO's *Professional Engineering Practice* (PEO, 2017), which includes a clause on whistleblowing:

> *"Sometime professional engineers find their advice is not accepted and that a client or employer has no intention of correcting the situation. If the engineer believes that after exhausting all internal resources, the health and safety of any person is being, or is imminently, endangered it may be necessary to report these concerns to some external authority…*
>
> *…this is a risky proposition since the whistleblower is violating moral and legal obligations owed to the employer or client… (however) whistleblowing is sometimes the morally correct response to an intolerable situation, especially if people are in danger."*

Of interest in the quote above is the recognition of the moral and legal ambiguity involved with fulfilling a Duty to Warn. Ultimately, however, the quote identifies the recognition of societal and moral obligations to third-parties who may be affected by a recognised risk, which in the context of TSFs, could include signs of imminent failure.

With the existence of an Act, design engineers practicing in Ontario are therefore held to comply with these clauses, with breach of these clauses being a chargeable offence.

While regulation may be a quantum shift in how the engineering profession operates in Australia, it may be the ultimate way in lowering the likelihood of engineers being caught unaware in regards to the expectations placed upon them to fulfil their duties to society. With the expectations being known, then the end goal of lowering the likelihood of design engineers being charged with civil and criminal negligence may be achieved.

Consideration should also be given to the inclusion of a discussion, if only a brief one, of the standard of care, duty of care and duty to warn of obvious risk in the relevant ANCOLD Guidelines. Such guidelines could include the Guidelines on Tailings Dams and Dam Safety Management, which, coincidentally, are being updated at the time of writing. The discussions would not have to be in-depth or extensive, however, should include relevant personal legal obligations considerations engineers should be aware of when undertaking work associated with dams and TSFs, which, ultimately could pose a high risk to third-parties.

Ultimately, these recommendations have been made with the aim that the expectations expected of design engineers are understood by the very design engineers that the expectations are applied to. With those expectations being understood, it is hoped that the likelihood of actions resulting in negligence and of TSF failures may be decreased, with the eventual outcome of reducing the rate of TSF failures.

Conclusions

The recent and highly publicised failures of TSFs around the world, most notably in Brazil, have resulted in greater scrutiny on the tailings industry. These failures resulted in the loss of life and, at times irreparable, environment damage and have led to far reaching impacts on the tailings industry from design to the calls for criminal charges against people associated with the failed TSFs, including the engineers who designed and reviewed the failed TSFs.

As shown in this paper, the legal framework in Australia and around the world presents a Duty of Care and Duty to Act to all professionals, including design engineers in the tailings field. Given the lack of formal legal education and training provided to design engineers, it is evident that the obligation to fulfil these legal duties are not well understood by the very engineers that must fulfil them. It was also shown that fulfilling the duty of care and duty to warn may be difficult and the design engineers may found themselves in a conflict of interest situation. There may be instances where the direct or indirect commercial pressures of a project are not in alignment with this fulfilment of an engineer's duty, or may result in intolerable risk to stakeholders who may not be aware of the risk that they are exposed to. Ultimately, engineers must be willing and able to address these pressures while fulfilling the duties that are applicable to them.

To address this gap in knowledge in regards to Duty of Care and Duty to Act, it is proposed that that industry bodies such as Engineers Australia aim to clarify and demystify these legal obligations and duties, as they are the best placed institutions to do so for the whole industry. In addition, it is recommended that an introductory course to duty of care and professional negligence is included in the undergraduate programs for professionals.

The authors of this paper believe that a better knowledge of professional duty of care of design engineers acting in the tailings industry will reshape the way design engineers operate resulting in a smaller number of future claims of professional negligence. Fulfilling professional duty of care by design engineers, including the appreciation of one's limitations and the need to consult more competent parties, may partly address the systematic causes of tailings dam failures, which in turn will result in a reduced number of tailings failures in the years to come.

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