Geomorphology 443 (2023) 108948

Contents lists available at ScienceDirect

Geomorphology

journal homepage: www.journals.elsevier.com/geomorphology

The role of geomorphology in environmental litigation: Insights from an East Texas case

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ARTICLE INFO

Keywords:
Soil erosion
Sedimentation
Expert witness
Litigation

ABSTRACT

This paper illustrates the scope and contribution that the discipline of geomorphology can offer in environmental litigation. The case in question was filed by two plaintiffs who contended that the construction of a storage facility on an adjacent property had caused significant disturbance of the topsoil, and that runoff from the impermeable surfaces (e.g., roofs, driveways) had exacerbated the problem by eroding and transporting soil and fill material from the facility directly into three ponds owned by them. They sued for $1.6 million to cover dredging, restoration of the ponds, and disposal of the sediment. Utilizing a range of geomorphological techniques, I was able to determine the most likely source area(s) of eroded sediment within the basin and quantify the extent to which the defendant's property contributed runoff and sediment to the ponds. The lawsuit was dismissed before ever going to trial. In the paper, I discuss the steps involved in the process of being an expert witness and also share some of the advice I have received from attorneys with whom I have worked. I emphasize the importance of setting any case study within a larger spatial context and encourage my fellow geomorphologists to become involved as experts in litigation because, in most instances, we can contribute to an appropriate outcome.

1. Introduction

In 2005, Stanley A. Schumm penned a commentary in *GSA Today* titled "Forensic Geomorphology" (Schumm, 2005). In this piece, Schumm reflects on his experiences as an expert witness[1] in legal proceedings over several decades and shares a list of items he calls "helpful advice" that was provided by attorneys that he had worked with during his career. Schumm's commentary is well worth reading, offering valuable insights into the rewards of applying geomorphological expertise within a legal context.

A decade later, Edward Keller published a more extensive piece titled "Being an expert witness in geomorphology" in this journal. Keller's focus is on his personal experiences and insights as an academic, teacher, and researcher, occasionally serving as an expert witness (Keller, 2015). He discusses the relevance of his work in these roles, specifically within the context of a case involving the Ventura River in California. Here, the construction of a flood control levee had constricted the river's flow into a narrower channel, resulting in an increase in unit stream power and increasing the potential for bank erosion and landslides. Like Schumm's commentary, Keller's paper serves as a valuable resource for those interested in the intersection of geomorphology and the legal system.

There has indeed been a history of litigation related to geomorphic disputes, especially in the sub-discipline of fluvial geomorphology and river boundaries. As noted by Donaldson (2009), well over one-third of the total length of international boundaries follows rivers or streams that are inherently dynamic natural features, and river boundary disputes are common. Donaldson (2011) provides an excellent discussion on this topic, including the 1892 US Supreme Court ruling on a boundary dispute between the neighboring states of Iowa and Nebraska. Another example is the so-called Red River Boundary Dispute of 1923, where the US Supreme Court decided where on the south bank of the Red River the Oklahoma-Texas boundary was located (Carpenter, 1925). More recently, the tension between legal rigidity and fluid dynamism along international river boundaries has been documented on the Mae Sai River along the boundary between Thailand and Myanmar (Wain, 2012;

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[1] An individual can be qualified as an expert "by knowledge, skill, experience, or education." The expert may testify in the form of an opinion if "(1) the testimony is based upon sufficient facts or data, (2) the testimony is the product of reliable principles and methods, and (3) the witness has applied the principles and methods reliably to the facts of the case." (Federal Rules of Evidence, 2020).

https://doi.org/10.1016/j.geomorph.2023.108948
Received 7 September 2023; Received in revised form 20 October 2023; Accepted 21 October 2023
Available online 23 October 2023

Miyake, 2023), the San Juan River along the border between Nicaragua and Costa Rica (ICJ, 2018), and the Danube River along a disputed section between Croatia and Serbia (Bickl, 2021), to name but three. These cases illustrate the complexities and challenges in determining boundaries and resolving disputes when dealing with dynamic natural features like rivers.

I have been an expert witness in various settings for almost 20 years. My initial foray into environmental litigation was in 2006 when I was asked to be a consultant and expert witness in a lawsuit filed by anti-coal groups in response to the fast-tracking of 11 new coal-fired power plants in Texas. My work focused on modeling the atmospheric fallout of mercury from the proposed power plants. Subsequently, I was called upon to testify before the Committee on Transportation and Infrastructure in the U.S. House of Representatives regarding the seriousness of the dangers posed by mercury deposition (Slattery, 2007). It was during this time that I first realized the potential impact of consulting work in informing policy, especially work involving expert testimony.

The following year, I was retained as an expert witness in a lawsuit in East Texas. The subject litigation centered around sedimentation in three ponds located on properties owned by two plaintiffs. They asserted that their ponds had been impacted by accelerated erosion from an adjacent property owned by the defendant. The plaintiffs contended that construction of a storage facility had disturbed the topsoil and that runoff from impermeable surfaces (i.e., roofs and driveways) had eroded and transported both fill material and disturbed soil directly into the ponds. An engineering firms report, based on a grain size analysis on samples from the defendant's property and areas around the ponds, appeared to support this claim. Consequently, the plaintiffs filed a lawsuit seeking compensation to dredge and restore the ponds.

I learned the role of an expert witness through hands-on experience. Although the subject matter (soil erosion and sediment transport) aligned with my expertise, I initially hesitated to engage in the suit because of concerns about potentially being portrayed as incompetent by eloquent lawyers during depositions or cross-examinations. I also had reservations about becoming involved in a high-stakes situation where real money was on the table. Certainly, being deposed or cross-examined can be intense and challenging, as I will discuss, and not everyone feels comfortable handling such situations. The fear of scrutiny and the potential for tough questions may discourage some from pursuing roles as expert witnesses. However, I have had the privilege of working with several outstanding lawyers over the years, each of whom has been immensely helpful in preparing me for cases and, most importantly, how to simplify complex concepts and communicate them effectively. This skill is crucial in ensuring that the expert's testimony is relatable and compelling for judges and juries.

In this paper, I discuss the process of being an expert witness using the East Texas case as a reference. My goal is to illustrate the scope and contribution that the discipline of geomorphology can offer in litigation involving environmental disputes. I also aim to share some of the advice I have received from attorneys with whom I have collaborated. Like Schumm's commentary, I hope to alleviate some of the fears and misconceptions surrounding expert witness work and encourage fellow professionals in the field of geomorphology to become involved in legal cases where their expertise can make a meaningful contribution.

2. Phases of litigation

In most cases, there are five phases of litigation that involve expert witnesses. I will summarize each phase for clarity:

1. Engagement and discovery:[2]

   I do not actively seek out expert witness work. Generally, I first hear about a case from a lawyer who contacts me at the university or who sends me an email. More commonly, I learn about cases through expert witness providers like The Expert Institute.[3] If the case falls within your area of expertise (and I strongly encourage you to only take cases that do), one of the lawyers will contact you to review the case, discuss any potential conflicts of interest, and negotiate your fees. This may seem uncomfortable at first, which is why I prefer using an expert witness provider where my fees are published and transparent. Generally, I charge between $275 and $325 per hour for tasks such discovery, fieldwork, report writing, travel time, meetings with the lawyers, and depositions. You may able to negotiate a higher rate for trial-related work, such as testimony and cross-examination. It is crucial to meticulously track the hours you spend on the case. Once retained, the next step is discovery during which your lawyers will provide you with all relevant case documents, including expert reports. Whether you're working for the plaintiff or the defendant, your focus should be solely on the science of the case and what transpired. However, be warned – discovery can be a time-consuming process. At this stage, you're also obligated to inform your employer if their case appears favorable or if it should be settled as soon as possible.
2. Your expert report:

   The next step in the litigation process involves the research itself and submitting your expert report. I will delve into this phase in more detail in the following section as I present the case study. Nonetheless, I want to offer two suggestions at this point that are particularly important. First, collecting your own data and forming your own conclusions stands as the most critical aspect throughout the entire litigation process. Keller (2015) emphasized this point strongly, and rightly so. Second, since the case will undoubtedly hinge on your pre-trial investigation and report, ensure that you are comfortable with *every* sentence in that document. Do not rephrase anything that your lawyers request if it alters your original intent in any way. Once you sign and submit that report, it becomes part of the record and should be the sole basis of any pre-trial deposition, should one take place.
3. Pretrial deposition:

   This phase involves testimony outside of a courtroom and can only occur after an expert report is submitted. During this phase, the opposing counsel has the opportunity to question you about your report, opinions, and methods. Their goal is to comprehend your intended testimony. Think of it as the opposing counsel's fishing expedition – they will attempt to raise topics that can later be used to undermine your courtroom testimony or diminish your credentials and credibility. This formal procedure takes place under oath and often reveals weak cases that prompt settlement discussions. While it can be one of the more intimidating aspects of expert witness work, proper preparation, reliance on your own data and conclusions, not

[2] Discovery is the process through which the parties to a lawsuit formally exchange evidence and information before a case goes to trial. Types of discovery include requests for production of documents – a demand that the other party provide copies of documents in their possession, or otherwise make the documents available for inspection and copying – and requests for depositions – the questioning of a witness under oath (Larson, Aaron (18 August 2016). "Conducting Discovery in a Civil Lawsuit". ExpertLaw. Retrieved 28 November, 2017).

[3] www.expertinstitute.com.

taking questions personally, and maintaining composure are essential. The most valuable advice I received here was to provide only the necessary information to answer the question asked. One lawyer told me: “If you feel compelled to elaborate on a concept, restrain yourself!” Your role, in essence, is to respond with clear, precise answers.

4. Direct testimony during trial:
   If the case is not settled, it proceeds to trial. During this phase, your opinions are presented to the court through questioning by your attorney. This phase is marked by straightforward and professional communication. You articulate your findings and opinions to support your side's case.
5. Cross-examination:
   This is the phase where the opposing counsel questions expert witnesses in an attempt to challenge their testimony. The goal is to weaken the expert's previous statements and potentially reveal inconsistencies between their deposition, direct testimony, and cross-examination. This can, quite dauntingly, be referred to as *impeachment*. This phase can certainly be stressful, as it involves scrutiny and attempts to challenge credibility. Again, if you have confidence in your testimony, your response to cross-examination should simply reaffirm the information provided during the deposition and direct testimony.

3. The context of the case, discovery, and my initial findings

As noted earlier, the subject litigation involved the sedimentation of three ponds located on properties owned by the plaintiffs. They asserted that their ponds had been infilled, and thus degraded, by accelerated erosion from an adjacent property owned by the defendant. I was retained to assess the extent to which the defendant's property contributed runoff and sediment to the main channel and, ultimately, whether the defendant's property was the primary source of the sediment in the ponds.

The properties in question are situated within a 94.4-ha drainage basin in East Texas, as depicted in Fig. 1. The defendant's property, outlined in red in Fig. 1, covers 9.35 ha, with 0.8 ha (or 8.6 %) of impermeable surfaces (e.g., roofs, roads). Their storage facility, comprising five buildings, was constructed on the property in 2002. Soils within the basin are primarily fine and very fine sandy loams. The two plaintiffs' properties, adjacent to that of the defendant, cover a further 18.7 ha of the basin. An ephemeral channel runs through the

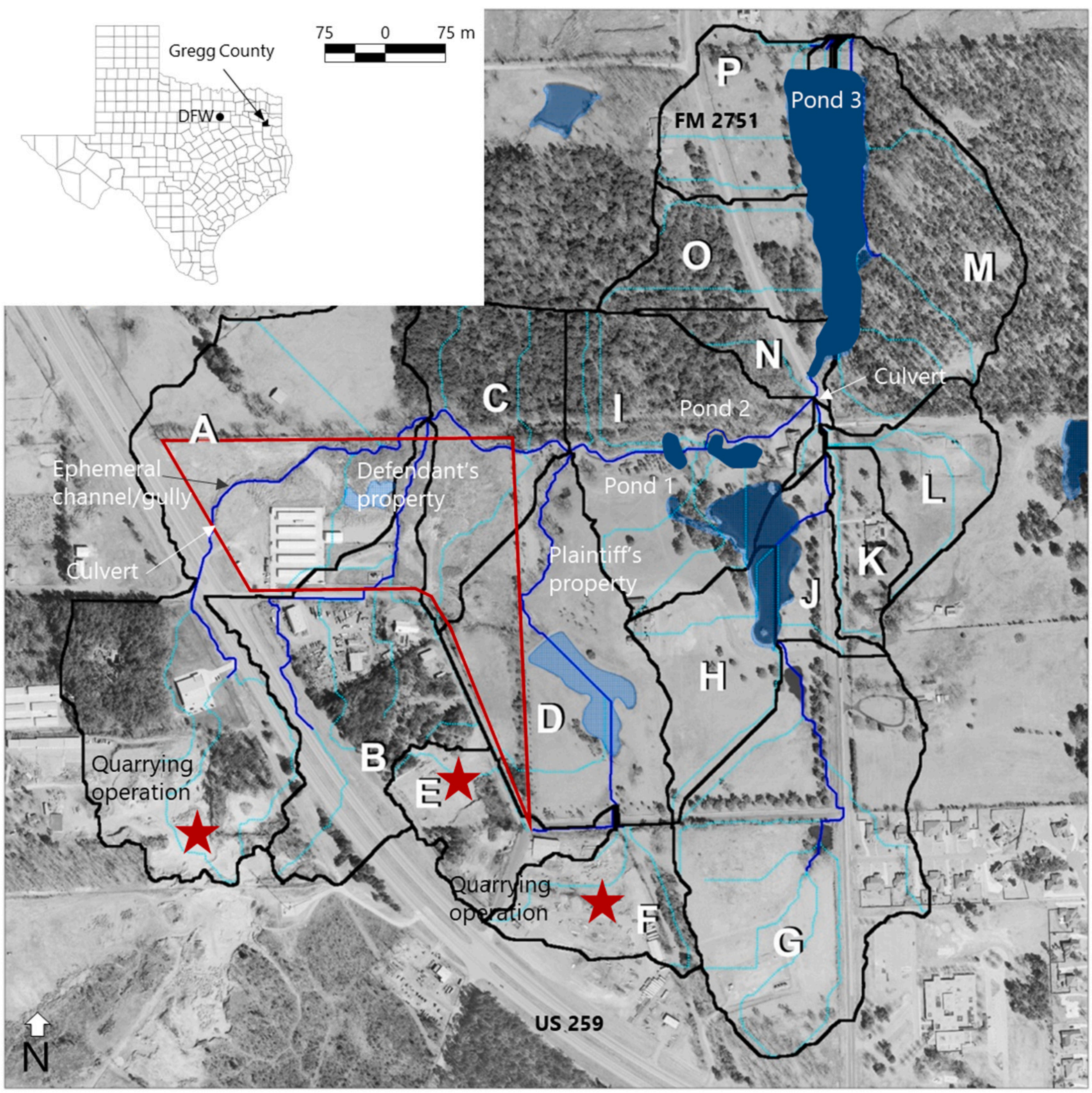

Fig. 1. The 94.4-ha study basin in Gregg County, Texas. The defendant's property is outlined in red and the three ponds under litigation are labeled Pond 1, Pond 2, and Pond 3. The basin is sub-divided into 16 sub-basins (labeled A through P) with minor and major drainage routes shown in light blue and dark blue, respectively. Major quarrying operations are shown by the red stars along the southern boundary of the basin. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

defendant's property before joining the main creek along the northern boundary of the plaintiff's properties (see Fig. 1). This creek first enters Pond 1, which was almost entirely filled with sediment, bypasses Pond 2, a spring-fed pond disconnected from the main channel, and then flows through a culvert under FM 2751 into Pond 3, the largest water body, covering 2.1 ha.

The lawsuit was based on an engineering report commissioned by the plaintiffs. Their experts collected ten surface samples from the defendant's property and two along Johnson Street to the south of the property, as illustrated in Fig. 2. Additionally, they collected 13 surface samples from around the perimeters of the ponds. A grain size analysis showed sand to be the dominant size fraction for soils on the defendant's property (a mean of 69.6 % sand). In Ponds 1 and 2, the sand-sized fraction ranged between 56.3 % and 64.1 %. Pond 3 was characterized by finer-grained material, with a mean sand fraction of 34.9 %. Curiously, the consultants concluded that defendant's property was the only likely source of the sediment in the ponds, given the similarity in the sand-sized fractions between the surface soils and the pond samples. They also argued that natural deposition in water bodies generally consists of clays and silts and that deposition of sand is a mark of accelerated, human-induced erosion and sedimentation. They estimated that $1.1 million was need to remediate the ponds.

Two aspects struck me as highly problematic upon review of the engineering report during this discovery phase. First, the plaintiff's case was based entirely on a grain size analysis of just 25 samples. From a geomorphic perspective, grain size alone provides limited insight into sediment provenance unless the source area in question is the sole origin of sand among all potential sources in a basin (Walden et al., 1997). If not, any inference as to direct source-sink linkages would be spurious unless it can be shown, by some other sediment “fingerprint” property, that the most likely source is that particular type of sand (e.g., Walling et al., 2012; Slattery et al., 1995). Second, the defendant's property, and the ponds in question, was never set into any hydrological or sedimentological context. The engineering report stated explicitly that there was a direct link between runoff generation and sediment delivery from the defendant's property to the ponds implying, in effect, uninterrupted transport along a conveyor belt of sediment flux. While the engineers acknowledged that “other potential sources of flow may exist within the basin”, they made no attempt to assess the potential contributions from these potential sources.

I responded to the engineering report as follows. First, I collected 120 samples from across the drainage basin from all *potential* source areas, including the defendant's property, a quarrying operation south of Highway 259 (which had never been mentioned in the engineering report), a number of drainage ditches, channel banks along the main stream network and slopes surrounding the ponds, as well as from the ponds themselves using auguring (see Fig. 3, left). Sampling was purposive, meaning that samples were taken from actively eroding sites, bare or exposed soil, hydrological flow paths (zones of obvious runoff, culverts, ditches, etc.) as well as areas of active deposition (on hillslopes, within the main channel, and the water bodies themselves). In-situ soil samples were taken to a depth of ~5 cm. All major soil types were sampled and lawyers representing both sides were always present during my fieldwork.

I then subjected the source material to a spectral analysis conducted on a high-resolution USB2000 fiber optic spectrometer. Because I had been reasonably successful in my Ph.D. doing sediment fingerprinting work and had published several papers on the topic, I felt this to be the most logical and scientifically robust approach. The lawyers agreed.

A bi-variate plot of the regression slopes of the spectral curves and the 700 nm reflectance values for the pond samples and surface samples on the Bowie (BoC), Cuthbert (CbE), and Kullit (KtB) soils is shown in Fig. 3, right. Statistically, these were the soils that clustered with, and were indistinguishable from, the pond samples. They were also the soil series proximal to the ponds with the Bowie series the dominant soil on the defendant's property and the Cuthbert series the dominant soil of the plaintiff's property. I concluded that the sediment in the ponds could simply not be linked to any single, dominant source, neither visually, nor statistically.

I then assessed the erosion potential of all soils within the basin and the degree of hydrologic/sedimentologic connectivity between the defendant's property and the sediment delivery system as a whole. This is critical because runoff generation and soil erosion are not always sourced in the same area. It turned out that the Bowie series had moderately low runoff potential (hydrologic group B), a moderate erosion hazard, and a K-factor (i.e., soil erodibility) of 0.32. The Cuthbert series, the dominant soil on the plaintiff's properties, is texturally identical to the Bowie, but runoff generation is more rapid and the erosion hazard potential is severe ($K = 0.37$). I included this information in my consulting report to emphasize that the most erodible soils with the highest runoff potentials were actually widespread on the plaintiff's property and geographically much closer to the affected ponds.

Finally, I used the revised USLE equation (RUSLE2) to quantify potential onsite erosion rates. Both the Bowie and Cuthbert soils had soil loss rates ranging between 4 and 4.5 t/ha/year. This helped contextualize for the lawyers the erosion rates that one *might expect* within this drainage basin rather than the actual amounts of soil delivered to the ponds. A considerable body of literature has shown that only a small proportion of soil eroded from hillslopes ultimately makes its way to a basin outlet, unless the linkage between on-site erosion and downstream yield is strong and direct (see, for example, Slattery and Burt, 1996; Slattery et al., 2001, 2002). My analysis showed that between the defendant's property and the basin outlet, no single soil dominates in terms of its erodibility and, by extension, its likely contribution of sediment to the ponds. I concluded by suggesting that the sediments in the ponds likely comprise a complex mixture of materials originating from various potential sources, including the sandy Bowie and Cuthbert soils. There was also a substantial contribution from material already in storage, from county ditches, culverts, and colluvium along foot slopes to the remobilization of bar deposits within the main channel.

I opined that it was a gross oversimplification to assert that the material in the ponds had come from a single source, namely, the defendant's property. I estimated that probably <20 % of the sediment in the ponds was sourced directly from the defendant's property and that this contribution had little to do with the land management on the property itself (i.e., the construction of the storage facility). Two major erosion features were on this property: a rill system that started at the fence line of the defendant's property on Johnson Street (see photograph A in Fig. 2) and a gully that started just northwest of the storage buildings and flowed eastward, eventually joining the main channel (see Fig. 4A, B and C). Both of these features were being incised by runoff being routed through culverts *upslope* of the defendant's property, primarily the quarrying operations in the headwater area of sub-basin A (see Fig. 1). There was simply not enough upslope catchment area for either the rills or gully to be the result of runoff generated on the defendant's property alone. Moreover, there was a deep channel on the plaintiff's properties near Pond 1 incising exposed Cuthbert soils with a direct link into the ponds (see Fig. 4D and E).

Well, I thought I had made a pretty good case. I had collected my samples carefully, made sure that the number of samples collected was statistically robust, had thought beyond the defendant's property in examining potential sources throughout the basin, and considered the most likely areas of runoff generation that could route sediment through the basin and into the ponds. I thought “case closed!” It turned out, it wasn't, especially when the plaintiff's lawyers brought in, quite literally, the heavy machinery.

4. Round two: drill rigs, Ford F-150s, and an East Texas jury that wasn't

The plaintiff's experts conducted a second round of fieldwork at considerable expense, collecting an additional 12 soil samples from the

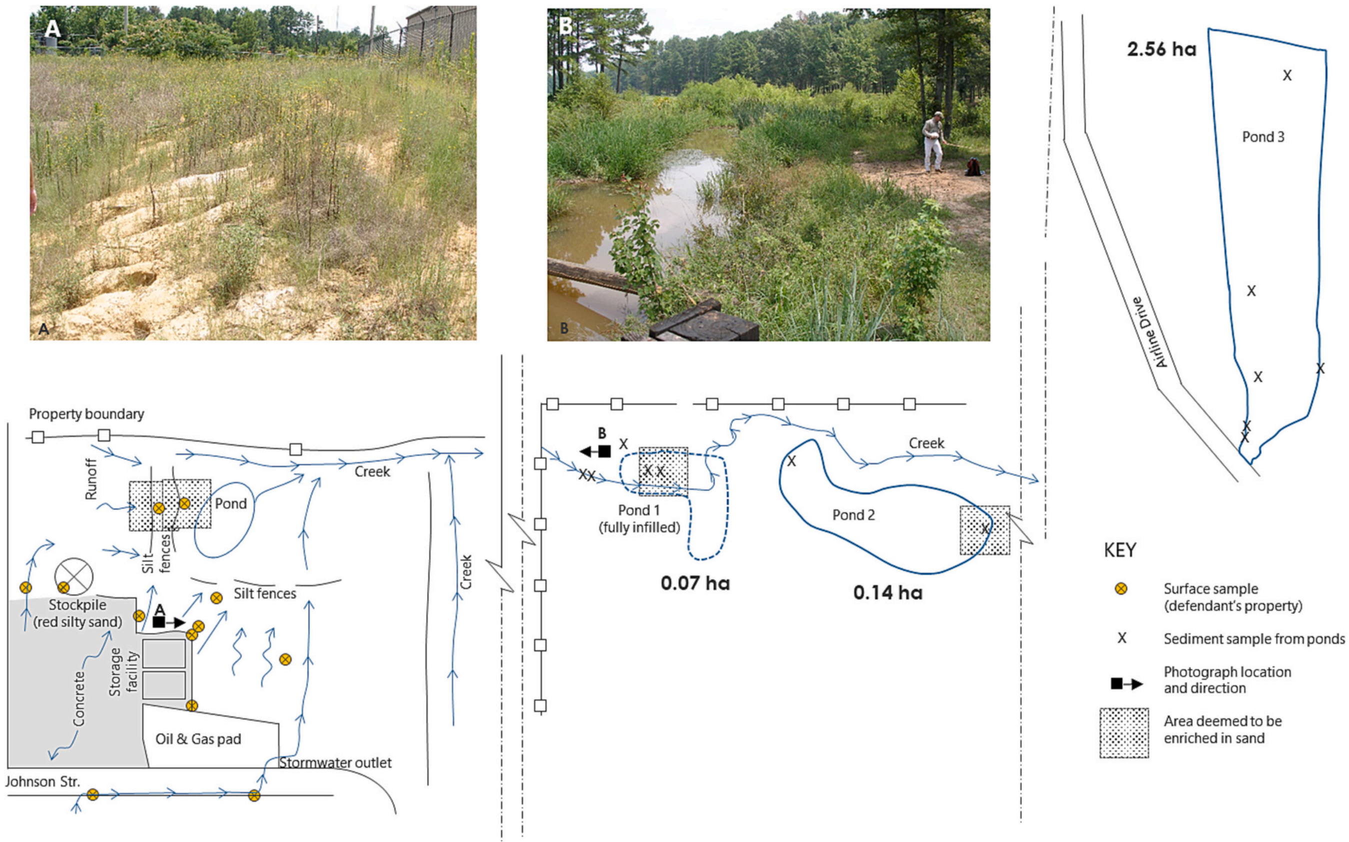

Fig. 2. The engineering company's original diagram of the defendant's property and ponds downstream along with their sample locations (re-drawn by me); the photographs are mine. Note how the consultants identify just two areas on the defendant's property (based on two samples) containing sand-rich material and a single location on ponds 1 and 2 with enriched sand.

defendant's property. They also drilled three cores into Pond 1 to depths of 3.1 m, 3.53 m, and 3.70 m, and three cores at the entry into Pond 3 to depths of 0.3 m, 1.52 m, and 2.13 m. As noted in their supplemental report, they analyzed "selected samples" from the cores to "better clarify source-sink relationships" which was presented to the lawyers and open to discovery. They gave no rationale as to why certain samples from the cores were selected while others were left out.

In what was a classic case of cherry-picking, the engineering team chose just four of the 12 samples taken from the defendant's property for a second grain size analysis. They reported a mean sand-sized content of 68.5 % ($\sigma = 4.75$), conveniently close to the 69.6 % stated in their initial report. Inexplicably, they then selected just two samples from one of the cores in Pond 1, at depths of 0.3 m and 2.4 m, and one sample from one of the cores in Pond 3, at a depth of 0.61 m, and reported a mean sand-sized fraction of 67 %. This turned out to be an error, because in their original data table, the three lake samples actually had an average sand-sized fraction of 55.3 % with significant within-sample variability ($\sigma =$ 29.2 %). Out of a total of 14 m of core drilled by the plaintiff's engineers, only three samples were used in the grain size analysis without any explanation as to why those depths were chosen or why the rest of the core was ignored. In fact, upon close examination of their core data, I found that the material taken from the ponds actually had far more silt and clay than sand. For instance, the 3.5 m core in Pond 1 had 0.61 m of silty sands at the surface but only silt and clay down to 2.6 m. In the core drilled to 3.7 m, silty sand was observed between 0.85 m and 1.37 m with silt, clayey silt, and clay deposited throughout the rest of the core. Overall, more than two-thirds of the total core lengths extracted from the ponds was comprised of fine-grained sediments (i.e., silt and clay), a fact simply ignored by the plaintiff's experts and lawyers.

In a new twist, quartz mineralogy, specifically color, was used by their experts to provide "a clear compositional fingerprint" for potential source material and sediment in the ponds. However, the plaintiff's experts deemed only three samples of native soil and one sample of fill material taken from the defendant's property "representative" of the source material, again without explaining exclusion of the other eight samples. On average, 60 % of the material used as fill for the storage facility was characterized as yellow quartz, while 50 % of the native soil on the defendant's property was characterized as cloudy quartz (Fig. 5). When plotted alongside the pond sediments, the consultants concluded that "the yellow core sample (i.e., Pond 1, core 1 at 0.91 m) was indistinguishable from the defendant's fill samples." The so-called "gray lake sediment samples" (i.e., Pond 1, cores 2 and 3 both taken at 1.52 m) were virtually identical to the native soil samples on the defendant's property – that is, they had similar concentrations of cloudy quartz, approximately 45–50 %. This conclusion was based on just seven core samples. Even more problematic was the fact that the three lake samples used in the grain size analysis were taken at completely different depths than those used in the mineralogical study.

The supplemental report submitted by the engineering company concluded, again, that "The primary source of sedimentation in the ponds (roughly 95%) is the highly eroded neighboring (i.e., defendant's) property" and that this has been "reaffirmed by the acquisition of detailed data linking sediments to their source." Further, they stated that "All the erosion off the defendant's property ends up in the creek and has nowhere to go but into Pond 1 and Pond 3…only 5% of the sediments in the lakes comes from up-gradient, off-site sources, with small amounts derived from channel banks." The total volume of sediment in the three ponds was revised up to 34,414 m^3 based on the coring, with a new estimated cost for remediation of $1.61 million.

After six months of field investigation, multiple reports and, undoubtedly, tens (and more likely hundreds) of thousands of dollars spent on lawyers and expert witnesses, our team had one nagging question

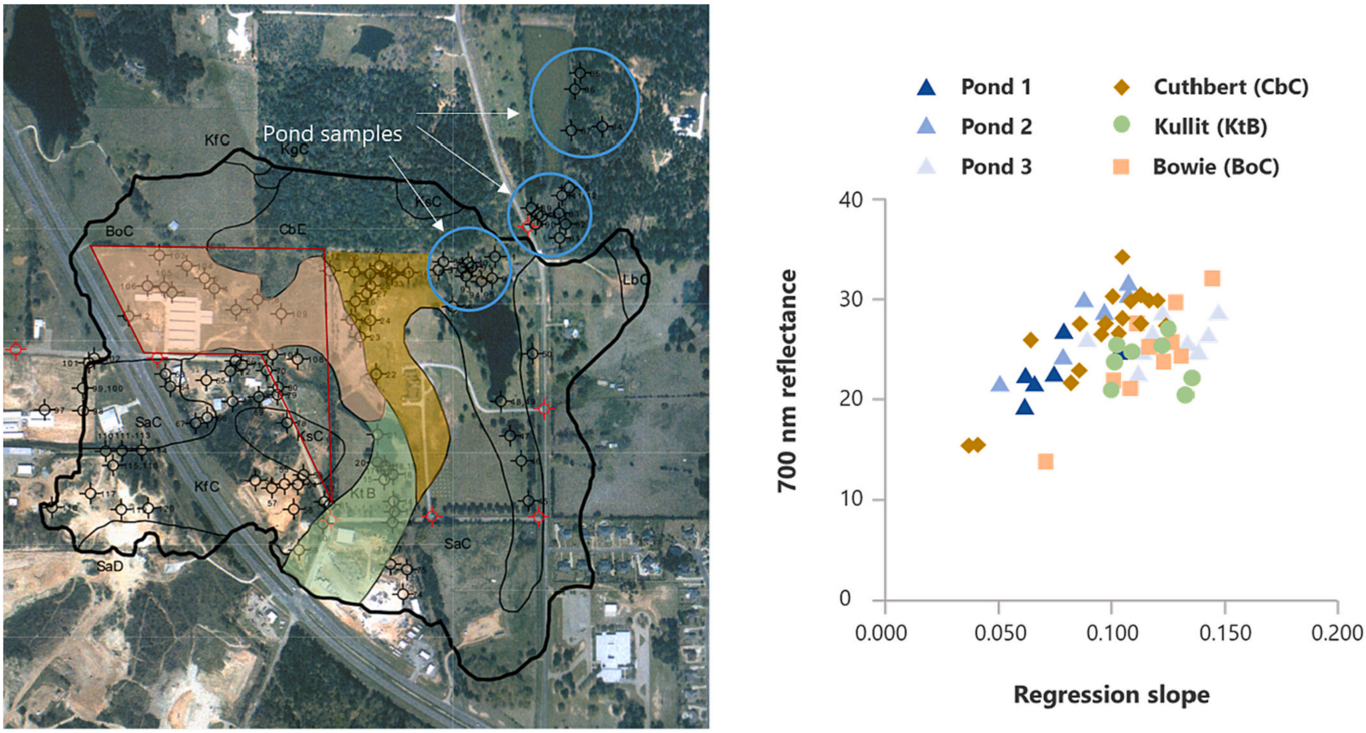

Fig. 3. (Left) The study basin showing the major soil series and locations of surface samples taken by me. The red symbols are ground-truth GPS locations. The blue circles capture the distribution of pond samples. (Right) Bi-variate plot showing potential source samples and pond samples in relation to the slope of the regression curves and reflectance at 700 nm. The slope of each sample's spectral curve between 525 and 600 nm was derived using linear regression. This region is the most critical in this study as iron minerals are most responsive in this range. The reflectance values at 700 nm were also used as a second line of evidence of sample clustering and similarity. Note here the proximity of the clustering between the Cuthbert soils and the sediments in Pond 1 and Pond 2, both of which are located on the plaintiff's property. The reflectance properties of the Sacul (SaC) and Kirvin (KfC) fine sandy loams did not overlap at all with the Cuthbert, Kullit, or Bowie samples, nor those in the ponds. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

prior to the case going to deposition and possibly trial: How do we show, in simple terms understandable to a jury, that it is improbable[4] that the majority of the sediment in the ponds came from this one 9.35 ha property? To some extent, the lawyers for the plaintiffs had the upper hand because they had a very simple story to tell: If the sediment on the defendant's property is sandy and is comprised of yellow and cloudy quartz, and the sediment in the ponds is sandy and comprised of yellow and cloudy quartz, then surely it is all one and the same? I worried that a jury might simply buy into this abductive approach – the classic duck test! And that's when it struck me: 32,700 m^3 (i.e., 95 % of the pond sediment) sourced from just 9.35 ha? I pulled out a legal pad and a calculator. Why on earth had I not thought of this earlier?

My simple and inexpensive calculations proved crucial. I explained to the lawyers that if 9.35 ha was the sole source of 32,700 m^3 of sediment, then approximately 0.35 m of topsoil would have to erode uniformly across the entire property to fill the ponds. Alternatively, if erosion had been concentrated along say a gully, then that feature would have to have been about 300 m with dimensions of 10 × 10 m. No such feature was ever found.

I explained further that excessive soil loss, as defined by the USDA, occurs when erosion removes topsoil at a rate >11 t/ha/year (equivalent to 7.3 m^3 of soil, assuming a soil bulk density of 1.5 Mg m^{-3}, or to a linear depth of 0.00073 m of topsoil/year). If erosion was occurring on this property at this excessive rate, it would take around 475 years to remove the 0.35 m of topsoil required to fill the ponds. To remove 0.35 m of topsoil within just 15 years, the time interval since the defendant started clearing land for construction, the erosion rate would have to have been approximately 345 t/ha/year. This rate would constitute the highest documented erosion rate on natural soils, globally. Finally, I noted that the estimated volume of sediment in the ponds could fill approximately 21,800 Ford F150 pickup trucks, assuming an average capacity of 1.5 m^3 of sediment per truck. The erosional features that I had surveyed on the defendant's property, including rills in fill material adjacent to the storage facility and the ephemeral gullies, amounted to about 1890 m^3 of material removed from the defendant's property, or about 5 % of the sediment volume in the ponds.

5. Lessons learned and concluding thoughts

The lawsuit never made it to trial. A judge dismissed the case due to insufficient evidence. There was no grand celebration, but the defendant's lawyers thanked me. In a rather touching note, they mentioned that my work had played a significant role in discrediting the engineering report and saving their client well over $1 million.

There is no doubt in my mind that my training as a geomorphologist served me well during this investigation. I gleaned several insights during the discovery process – insights that, as geomorphologists, we simply take for granted in our daily endeavors.

First, it is crucial to place a study reach (and in this case, the three ponds) within a broader geomorphic, spatial context. I learned this firsthand during my Ph.D. fieldwork measuring rill erosion on agricultural fields in Oxfordshire. My Ph.D. supervisor, Dr. Tim Burt, encouraged me to walk the extent of the basin and "look over every hill." In doing so, I stumbled across a marvelous thalweg, or valley, rill system in an adjacent hillslope hollow, a discovery that serendipitously led to a publication (Slattery et al., 1994). As geomorphologists, we always seek to uncover driving variables both upslope (or upstream) and downslope

[4] The burden of proof here was 51 %, meaning that we just had to show that it was more likely than not that the sediment in the ponds had not come from just the defendant's property.

Fig. 4. Photographs of erosional features on both the defendant's and plaintiff's properties. (A) at the culvert along the western boundary of the defendant's property (see Fig. 1); (B) looking downstream from photograph A; (C) the gully northwest of the storage facility (see Fig. 1); (D) an incised channel on Cuthbert soils proximal to Pond 1; (E) aerial image looking east toward the ponds showing exposed Cuthbert soils on the plaintiff's property.

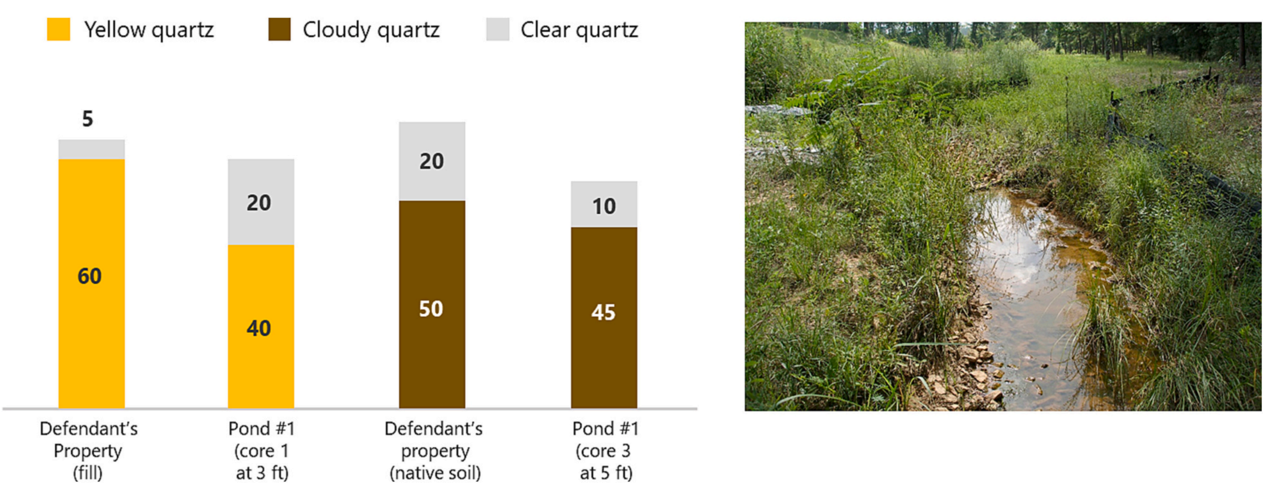

Fig. 5. Quartz mineralogy of fill and native soil on the defendant's property and core material taken from Pond 1 (redrawn by me form the original engineering report, for clarity). The photograph is mine and shows the entry to Pond 1 looking east.

(or downstream). In this case, the engineers had focused solely on the defendant's property as the only possible source area, ignoring other potential runoff areas and sediment origins. They had overlooked the activities and land cover upstream of the defendant's property, all of which had far greater potential to generate runoff during rainstorms and erode and transport sediment downstream.

Second, and closely linked with the concept of spatial context, is that of connectivity, a widely used conceptual framework within geomorphology. Specifically, connectivity describes the efficiency of material transfer between geomorphic system components such as hillslopes and rivers or longitudinal segments within a river network (Wohl et al., 2019). Nowhere in their reports did the engineers consider hydrological, sediment, or landscape connectivity, including the possibility that eroded sediment could be stored anywhere along the sediment conveyance route, the potential residence times of stored sediment within the delivery system, the connectivity pathways within the basin, or that material might originate from elsewhere within the basin. Their perspective was an overly simplistic input-output, source-sink relationship. In focusing solely on the defendant's property as the source of the eroded material, they never asked the key question: how connected or coupled is component A (i.e., the property and the ephemeral channel/gully) to component B (i.e., the ponds) within this system. As highlighted by Brierley et al. (2006), understanding connectivity between landscape compartments is pivotal in explaining spatial relationships and the behavior of biophysical fluxes.

Third, cherry-picking will almost always be discovered and exposed. The fact that the engineers had taken so few samples (and then only done so from the defendant's property) to quantify sediment-source ascription, and had provided no explanation as to why >5 % of the pond material had been analyzed, was glaring. In addition, they used an inappropriate method (i.e., grain size analysis) to quantify source-sink relationships and had ignored many potential source areas within the basin. The first rule of any sampling is, of course, to ensure that the sample size is representative and statistically viable. Yes, my 120 surface samples seemed excessive (the attending lawyers didn't mind as they were being paid by the hour to monitor my work), but that was the required number across all possible source areas to allow any statistical inferences to be made.

Finally, always assume your field notebook will end up in a court of law. Simply put, be diligent in your sample collection. The plaintiff's lawyers asked me questions relating to sample size, possible sample contamination, sample storage, etc., on several occasions during my fieldwork.

Although I wasn't deposed in this instance, I have been in several other cases. As noted earlier, expert deposition (and cross-examination) can be intimidating, but if you are well prepared and have done a thorough and professional job, you really have nothing to fear from being deposed or cross-examined. For the most part, I have enjoyed the give-and-take between myself and opposing counsel. I have also found that lawyers highly value professors as expert witnesses because of our experience in presenting complex material to diverse audiences, including students, which can translate well to presenting information in a clear and understandable manner for a judge or jury.

Ultimately, the decision to become an expert witness is a personal choice that centers on your comfort level. If you have confidence in the value of your expertise and your ability to communicate effectively, you can discover ways to navigate the challenges and make a positive impact as an expert witness.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Michael Slattery reports financial support was provided by Anderson, Smiley, and Riddle Law Firm. This was for paid expert testimony.
Michael Slattery reports a relationship with Burns Charest Law Firm that includes: consulting or advisory and paid expert testimony.
Michael Slattery reports a relationship with Nix Patterson Law Firm that includes: consulting or advisory and paid expert testimony.

Data availability

Data will be made available on request.

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