Ecosystem recovery of Tampa Bay following the 2021 release of phosphate mine wastewater from the Piney Point facility

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## Abstract (150-250 words)

Mining activities can support local and global economies, yet also impose significant consequences for the natural environment. Phosphate mining in central Florida has been ongoing for decades and many facilities present risks to freshwater and coastal aquatic environments in the state. In 2021, a breach in the liner of a wastewater holding pond at Piney Point, a legacy phosphate processing facility, resulted in the emergency discharge of 215 million gallons of highly acidic and nutrient-laden (nitrogen, phosphorus) process water into Tampa Bay. A multi-agency, event-response monitoring program resulted and documented subsequent ecosystem impacts. Short-term declines in water quality were observed, with a notable harmful algal bloom and substantial fish kills occurring three months after the initial wastewater release. Acute spills such as the 2021 event threaten to reverse past successes in seagrass and ecosystem recovery in Tampa Bay. Currently, the site is being closed and efforts to mitigate or prevent future impacts are ongoing. This chapter will present the historical context and management of Piney Point as a precursor to the events of 2021, while providing quantitative examples of the Bay’s response relative to the long-term recovery of the Bay. The role of the Tampa Bay Estuary Program (TBEP) as a non-regulatory institution that works to build public and private partnerships for environmental management will also be explored, with emphasis on TBEP’s role coordinating monitoring efforts and disseminating communication products.

## 1 Introduction (500-1500 words)

The contemporary history of Tampa Bay, Florida is an exemplary model for how collaborative efforts among public and private entities can lead to long-term improvements in the environment. In February 1974, a news segment airing on the television program Sixty Minutes drew national attention to the effects of population growth and unchecked development in the Tampa Bay region. Nutrient discharges, particularly nitrogen, trigger algal blooms that reduce light penetration resulting in loss of seagrasses. The Bay’s natural resources, including key fisheries dependent upon healthy estuarine habitats like seagrass, showed evidence of stress from an increasing human population in the watershed. The discharge of minimally treated wastewater into Tampa Bay was a culprit for many of these issues. Over the following decades, efforts to restore Tampa Bay were successful in reducing nutrient loads from wastewater and other external sources by 2/3 of levels observed in the 1970s (Greening et al., 2014; Greening & Janicki, 2006). By 2016, seagrasses had recovered to an all-time recorded high of 41,656 acres, exceeding the management goal by several thousand acres (Sherwood et al., 2017).

Efforts contributing to the recovery of Tampa Bay were the product of multiple factors, some opportune while others more intentional. In the 1960s, a growing nationwide environmental movement influenced public sentiment on how unregulated economic growth and development can severely harm the environment. Notable events such as the Cuyahoga River catching on fire and widely read texts like “Silent Spring” were influential factors that motivated change in a national environmental ethic. These sentiments trickled down to Tampa Bay communities as local environmental disasters combined with massive population growth led to public calls for regulatory reform and environmental restoration (Bennett, 2024). Initial focus was primarily on the discharge of poorly treated sewage directly to the Bay, as legislation was ultimately passed that required all wastewater treatment plants to upgrade to advanced technologies to remove excess nutrients before the water was returned to the environment or beneficially reuse 100% of the treated water (Johansson, 1991). By the 1980s, additional state legislation led to tighter controls on stormwater pollution to remediate additional sources of nutrients. These efforts were reinforced at the federal level with enactment of the Clean Water Act in 1972 combined with access to federal grants to construct municipal wastewater treatment plants. Gradually and over several decades, tighter regulation of pollution – motivated by public concern over the effects of population growth – produced water quality improvements and the seagrasses returned. Baywide recovery was also supported by hundreds of habitat and infrastructure restoration projects lead by numerous entities (Beck et al., 2019).

Local environmental groups were and continue to be key players in coalescing public support to improve water quality in Tampa Bay (Gross & Hagy III, 2017; Sherwood et al., 2016). The Tampa Bay Estuary Program (TBEP), in particular, has been a consistent voice over the last three decades that has worked to build partnerships to restore and protect the Bay’s resources. This work is implemented through a scientifically sound, community-based management plan that outlines distinct actions to protect water and sediment quality, fish and wildlife, and the community. The TBEP is part of a broader National Estuary Program consisting of 28 similar programs around the country that have been established as Congressionally-recognized “estuaries of national significance”, each with their own local mission. Since 1991, the TBEP has worked to engage communities, private businesses, and local governments to work towards the common goal of a healthy Tampa Bay. The TBEP also facilitates the Tampa Bay Nitrogen Management Consortium (TBNMC), with representatives from public and private entities that have a shared responsibility to control nutrient pollution sources to Tampa Bay. The TBNMC has worked to reduce nitrogen loads as a key water quality pollutant since the mid-1990s, with private and public permitted wastewater and stormwater sources being the primary participants. The management approach is simple; reduced nitrogen loads will reduce algal growth, promoting a light environment in the water that is supportive of seagrass growth (Janicki et al., 2000; Johansson & Greening, 1999). The TBNMC has quantified and allocated sources of nitrogen among entities that directly or indirectly discharge to the Bay, with total allocations not to exceed the capacity of the Bay to assimilate these nutrients (Janicki & Wade, 1996). The Florida Department of Environmental Protection (FDEP) and US Environmental Protection Agency (USEPA) maintain regulatory oversight.

Despite the nationally recognized success story of Tampa Bay, current challenges have emerged that threaten past achievements and bring into question the effectiveness of existing management paradigms. From 2016 to 2022, seagrasses declined baywide by over 11,000 acres, falling well below the management target of 40,000 acres (Beck et al., 2024). These declines were notable because water quality goals were generally met in successive years of seagrass decline, suggesting that additional factors beyond established water-quality targets and regulatory thresholds were driving this loss. Recent interest has shifted towards climate change as a potential culprit, as extreme temperatures and changes in precipitation may be stressing seagrasses beyond their optimal tolerance ranges (Beck et al., 2024; Oliver et al., 2018; Sherwood & Greening, 2013). These additional stressors mean that further reductions in nutrient loads may be needed to account for external climate factors that are difficult, if not impossible, to control at the local scale (Stantec Consulting Services, Inc., 2025). Resilience of the Bay to assimilate nutrient inputs has likely been reduced as shifting ecological baselines from climate change cause regional managers to reconsider the effectiveness of previously-established water quality targets and thresholds.

Reduced resilience of Tampa Bay to respond to management efforts that control nitrogen loads threatens to undo the years of collaborative work in restoring seagrasses. Further, unanticipated events may push the Bay beyond a tipping point to undesirable conditions similar to the past as the Bay may no longer have the capacity and resilience to process excess nutrient inputs. Events in 2021 were a substantial test for the management of Tampa Bay that provided an unintentional, system-wide experiment for how the Bay’s resources respond to acute nutrient inputs. The Piney Point facility is located on the southeast shoreline of Tampa Bay and is a legacy phosphorus fertilizer processing facility that has been inactive for over twenty years ([Figure 1](#fig-map)). Large amounts of wastewater – a byproduct of historical processing and closure activities – remain on site with no useful application given the chemical characteristics of the water and the challenging logistics of its safe removal. Central Florida has a long and complicated relationship with phosphate mining and fertilizer production (Nelson et al., 2021). While these activities support economic growth and agricultural productivity, there are often direct and unintended consequences for the natural environment. Piney Point embodies this relationship, as fertilizer exported outside of the region has had societial and economic benefits, whereas wastewater stored on site has been released to Tampa Bay on more than one occasion with negative impacts ([Figure 1](#fig-map)).

In April 2021, a tear in the plastic liner of the southeastern holding stack (NGS-S) at Piney Point was detected, and the release of wastewater into Tampa Bay was authorized by FDEP to prevent catastrophic failure of the holding walls (Beck et al., 2022; Morrison et al., 2023; Nelson et al., 2021). The decision to discharge millions of gallons of wastewater into Tampa Bay from Piney Point was needed to safeguard property and human life near Piney Point, despite the anticipated environmental consequences. Over 215 million gallons of wastewater were released, introducing 205 tons of nutrients to lower Tampa Bay over a ten-day period, exceeding the amount that is typically introduced annually from all other sources. The TBEP, in collaboration with multiple local, regional, and state entities, coordinated a response-based monitoring effort to document the effects of this release on the Bay’s resources. Several dramatic effects were observed over the months following the initial release, the most notable being a massive bloom of the red-tide organism *Karenia brevis* that was likely fueled by the nutrient-rich wastewater from Piney Point that continued to circulate in the Bay following the emergency release (Chen et al., 2023). Red tide blooms produce a potent neurotoxin that is fatal for wildlife exposed for sustained periods. As a result, more than 1800 tons of dead fish were recovered from Tampa Bay in July 2021.

This chapter will provide an overview of the history of the Piney Point facility and the effects on the Bay during and after the wastewater release, including incidents that occurred before 2021. This information is presented in the context of the long-term recovery of Tampa Bay, the effects on seagrass resources, and how the history of local partnerships were important for the response-based effort. The reader should gain an understanding of how past events, both historically and leading up to 2021, influenced the decision to release wastewater to Tampa Bay and what actions can be taken in the future to prevent similar events from occurring. The role of TBEP as a facilitator for Bay management will be emphasized, and the reader should reflect on how past activities of the program were important for responding to the Piney Point event, in addition to future challenges for managing Bay resources based on the details presented herein.

## 2 Background (1000-2000 words)

The “Bone Valley” in central Florida has supported a multi-billion dollar mining industry for several decades (Henderson, 2004). Its namesake refers to the geological characteristics of the region, or karst geology, where fossilized marine organisms have created a limestone base overlying a freshwater aquifer. This limestone is rich in phosphorus deposits, which are mined for use as a main ingredient of commercially available fertilizer, either for residential use or large-scale agricultural production. Consequently, Tampa Bay waters have relatively high concentrations of phosphorus to which aquatic organisms have adapted over geologic time scales (Wang et al., 1999). Additions of historically scarce nutrients, like nitrogen, can substantially alter the balance and pace of primary production in the estuary. Because Tampa Bay is “nitrogen-limited”, water quality improvements have focused on reducing external sources of nitrogen inputs to the Bay (Greening et al., 2014). However, byproducts from fertilizer production and the resulting fertilizer products themselves are rich in both phosphorus and nitrogen. Fertilizer processing facilities are often located near distribution centers like marine ports, and the export of fertilizer is a primary function that the ports of Tampa Bay support. As such, both the production and export of fertilizer can introduce significant external nutrients that affect the Bay’s water quality.

The production and distribution of fertilizer is a waste-intensive process. For every one kilogram of useful fertilizer that is produced from raw phosphorus ore, five kilograms of waste are created (U.S. Environmental Protection Agency, 2025). This waste is called phosphogypsum and it has minimal commercial applications, owing primarily to its radioactive characteristics and regulatory controls that limit its use after production. Phosphogypsum is typically stored on-site as large stacks (or “gypstacks”) that are visible from miles away and are often the only topographical features on the flat Florida landscape. Phosphogypsum is initially produced as a slurry during fertilizer production. The gypstacks are formed as the solid materials settle out of the slurry, leaving a low-pH wastewater with similar chemical characteristics as the solid phosphogypsum. Piney Point historically produced diammonium phosphate ((NH)HPO), and the wastewater stored on site is high in both nitrogen and phosphorus. This wastewater also has no practical use, and its disposal through treatment or export elsewhere can be cost-prohibitive. As a result, phosphogypsum stacks and their wastewater persist long after fertilizer production stops, with 17 such examples in the Tampa Bay watershed [25 total in Florida; Florida Department of Environmental Protection (2025)]. Distribution of fertilizer at port facilities can also introduce substantial nutrients to surface waters primarily through losses during physical transport on or off a vessel. Although regulation and adoption of best practices has greatly reduced “material losses” directly to the Bay from these activities, nutrient loads from fertilizer transport at ports are still estimated as a non-negligible portion of the overall nutrient budget for Tampa Bay (Janicki Environmental, Inc., 2023).

The Piney Point facility has a long and complicated history of ownership and management (see supplement to Beck et al., 2022; Henderson, 2004). Fertilizer production began in 1966 when the land was purchased by Borden Chemicals. Early reports described environmental concerns related to surface water contamination in Bishop Harbor (a small subembayment of Tampa Bay immediately adjacent to Piney Point), suspected groundwater contamination from industrial solvents, and air pollution from emissions produced during fertilizer production. Mulberry Phosphates, Inc. acquired the facility in 1993 and operated it until 2001 when the company declared bankruptcy, after which closure and regulatory oversight was transferred to FDEP. Mulberry Phosphates was a prominent fertilizer production company in Florida at the time and was also responsible for an unintentional spill in 1997 of fertilizer process water into the Alafia River, the second largest tributary to Tampa Bay, that resulted in a massive fish kill (DiPinto et al., 2001). Similarly, wastewater from Piney Point was released to Bishop Harbor in 2001 due to tropical storm activity and again from late 2003 to early 2004 to ease pressure on the gypstacks. The impacts of these events were not well studied, although Garrett et al. (2011) documented occurrences of potentially harmful algal species near the discharge site, and Switzer et al. (2011) noted increased macroalgal blooms. Wastewater was also barged offshore to the Gulf of Mexico during this time as another attempt at maintaining integrity of the facility. HRK Holdings, LLC purchased Piney Point in August 2006 through an administrative agreement with FDEP. With continued oversight by FDEP, HRK agreed to maintain Piney Point such that any future uses must protect and be compatible with stack closure and long-term care, as defined in their agreement.

Over the course of its ownership, site management decisions by HRK contributed to further decline in the holding capacity of the gypstacks at Piney Point. A port expansion project at Port Manatee near Piney Point produced dredge material that HRK agreed to store in the NGS-S holding pond ([Figure 1](#fig-map)), further reducing holding capacity of the facility. Wastewater was again released in 2011 to Bishop Harbor as a result of compromised plastic liner in NGS-S, where the addition of dredge material and seawater was suspected as the cause. HRK Holdings filed for Chapter 11 bankruptcy in 2012 citing expenses associated with the port expansion project and the fallout from the environmental impacts. Although HRK maintained majority ownership of the site, portions of the property were sold to third parties to alleviate some of the financial burden from the bankruptcy settlement. By 2021, the inability of NGS-S to continue to hold wastewater and dredge material was evident as a leak was identified in NGS-S and later confirmed as being caused again by another tear in the plastic liner of the holding pond. Concerns of public safety and potential damage to property motivated the decision to release untreated wastewater from NGS-S directly to Tampa Bay near Port Manatee, as authorized by an emergency order from FDEP.

From March 30th to April 9th, 2021, 215 million gallons of wastewater were released from Piney Point into Tampa Bay (Beck et al., 2022). A year’s worth of external nutrient inputs entered lower Tampa Bay during this ten-day period. Given anticipated environmental impacts, the TBEP coordinated a multi-agency, event-response monitoring program to document the effects of the release on the Bay’s natural resources. Public, private, and academic partners collected thousands of water quality samples, measured seagrass and macroalgae coverage, documented changes in sediment quality and the organisms that live on the Bay bottom, and assessed algal community changes. Monitoring efforts were guided by a hydrodynamic flow simulation model developed by the College of Marine Science at the University of South Florida (Liu et al., 2024). This model provided an assessment of where the released water was likely to travel, thus providing guidance on where sampling should occur each week. The TBEP provided support for these efforts by having regular meetings with partner agencies to coordinate sampling, serving as a data warehouse for synthesizing monitoring information, creating a public dashboard to communicate changes to the public in near real time, and disseminating monthly one-page summaries that distilled complex environmental data into the most meaningful observations (Beck et al., 2023; Tampa Bay Estuary Program, 2022). In addition, TBEP staff provided dozens of interviews for local and national media outlets as expert commentary on the event.

Intensive monitoring of Bay resources continued for six months following the initial release. Throughout this period, several impacts were observed (Beck et al., 2022; Morrison et al., 2023). First, an immediate and expected response in the algal community near the discharge point was observed, as a bloom of commonly-occurring diatoms quickly utilized the nutrients ([Figure 2](#fig-wqchange)). The bloom was short-lived and dissipated by the end of April, after which blooms of filamentous cyanobacteria (*Dapis* spp.) were observed near the port and at locations south, often observed covering seagrasses or floating on the surface. Increases in macroalgal species were also observed along seagrass monitoring transects within several months of the initial release (Scolaro et al., 2023). The cyanobacteria and macroalgal blooms decreased in abundance by July, when concentrations of the red-tide organism *Karenia brevis* increased dramatically in the Bay. Red tide was first observed outside of Tampa Bay on April 20th, first measured at concentrations considered to be a bloom in the Bay proper on May 23rd, increased to high bloom concentrations (> 1 million cells / L) by late June, and peaked on July 4th at greater than 10 million cells / L in the middle of Tampa Bay ([Figure 2](#fig-wqchange)). Red tide is typically limited in Tampa Bay as freshwater inputs from major rivers lower salinity below the optimal tolerance range for these organisms. However, low rainfall during the first half of 2021 contributed to higher than normal salinity that produced favorable conditions for red tide, in addition to increased availability of nutrients from the Piney Point discharge. As a result, brevetoxins produced by the red tide caused a massive fish kill throughout the Bay, and an estimated 1800 tons of dead fish were recovered. The effects of red tide on fish in Tampa Bay were also reflected in notable increases in public reports during July to a state fish kill hotline ([Figure 3](#fig-fishkill)). Compared to other years, 2021 was a distinct outlier in the number of reported fish kills. Numerous reports of manatee mortalities were also received during this time (Florida Fish and Wildlife Conservation Commission, 2025).

By September 2021, conditions in the Bay were visibly similar to those prior to the release from Piney Point ([Figure 2](#fig-wqchange)), although monitoring and additional research continued to better understand long-term effects. A study published two years later demonstrated that wastewater from Piney Point dispersed much further than anticipated, with seawater at a control site over 30 miles to the north of the mouth of Tampa Bay having a chemical signature similar to the discharge (Morrison et al., 2023). Seagrasses, although not showing any notable changes in 2021, declined in total cover on the eastern shore of Tampa Bay based on a comparison of estimates from aerial imagery obtained during the winter of 2020 and 2022 (i.e., pre- and post-discharge, [Figure 4](#fig-seagrasschange)). However, seagrasses consistently declined baywide since 2016 and it is difficult to assess the role of Piney Point in the observed 2022 decline. Further work has demonstrated that phosphorus and nitrogen from wastewater discharge from Piney Point, 2021 and previous, can be stored in bottom sediments as a potential source of nutrients (Chappel et al., 2025). These findings highlight the need to better quantify sediment nutrient sources that have likely been influenced by Piney Point discharges, especially when stored nutrients can stimulate algal blooms in the water column during storm events that resuspend sediments. Lastly, the fate and effects of lesser studied contaminants from Piney Point have also been a concern. Elevated microplastic concentrations were observed near the Skyway Bridge at the mouth of Tampa Bay shortly after the initial wastewater release, possibly from degradation of the plastic liner in the holding ponds (S. Gowans, Eckerd College, personal communication, April 2025). Microplastics have widespread distribution in Tampa Bay and future efforts should focus on source mitigation to prevent further negative impacts on Bay habitats and wildlife (Gowans & Siuda, 2023; Vandale et al., 2023).

Public response to the events of 2021 was a significant factor influencing future closure plans for Piney Point. Motivated by public concerns on the environmental impacts, a lawsuit was filed against HRK holdings by several prominent local conservation groups shortly after the discharge was authorized for release in 2021. Litigation occurred in the years following and on September 18th, 2024 a US District federal judge ruled that HRK was in violation of the federal US Clean Water Act, despite receiving a permit from FDEP to discharge the wastewater (United States District Court, Middle District of Florida, 2024). This ruling ordered HRK to pay $56,460 for each day wastewater was released to public waters, totaling $846,900 for the duration of the event. FDEP concurrently agreed to fund additional monitoring to assess long-term impacts, with $75,000 paid to the TBEP to organize these efforts. During litigation, public calls for the closure of Piney Point led to the development and implementation of a full closure plan for the facility as adopted and implemented by FDEP (Ardaman & Associates, Inc., 2022). These plans included using an independent third party as a court-appointed receiver to oversee the closure process, with specific actions to treat the wastewater onsite prior to pumping the water underground using a newly constructed deep-well injection site that was fully functioning by April 2023. Wastewater was also sent to local treatment plants to expedite the process. Once all wastewater is removed, the remaining ponds will be filled and capped with soil to reduce future stormwater management needs at the site. As an example of closure progress, [Figure 5](#fig-capacity) shows the removal of water from NGS-S over time, as well as the ability of Piney Point to accommodate additional rainfall contributing to stormwater capacity onsite as wastewater is treated and removed. As of this writing, only one of the four holding ponds at Piney Point has been successfully closed.

Piney Point has brought additional attention to the impacts of phosphate-mining facilities on the environment, with a renewed focus on the risks from other facilities in the Tampa Bay watershed. Florida has 25 such facilities, with over 2/3 of these in the Tampa Bay watershed alone (Florida Department of Environmental Protection, 2025). Only two of the seventeen gypstacks in the watershed are still actively processing fertilizer, whereas the remainder are closed or inactive. In some respects, the approval by FDEP to remove wastewater by deep-well injection at Piney Point may set a precedent for future closure activities since long-term plans for many of these facilities have not been established. Deep-well injection has been proposed in the past to facilitate closures of inactive phosphate mining sites, although the method has not been viewed favorably by the public given uncertainty about the associated risks or simply misinformation about deep-well injection. Although wastewater is pumped much lower than the freshwater aquifer that serves as a source of drinking water for many in the state, the extent to which this water could migrate to other aquifers or surface waters is not well understood. Perhaps a larger risk is integrity of the injection site since leaks at more shallow depths could also introduce the wastewater into drinking water sources. Phosphogypsum has also been proposed for use as a base material for road construction and FDEP has allowed a preliminary test site to assess the risks of doing so. Critics argue these materials may pose safety risks to road workers and serve as an additional source of contamination for surface water. Regardless of whether these methods are a practical means of safely and responsibly closing inactive mining facilities, their proposal does suggest recognition by fertilizer producers that these facilities are substantial liabilities that require more attention to mitigate their external impacts. It is unclear whether current state and federal regulatory requirements appropriately factor in the full scope of the environmental and financial liabilities that these facilities pose in Florida.

## 3 Student Activities (500-1000 words)

### 3.1 Classroom discussion questions

1. This chapter focused on the long-term recovery of Tampa Bay and its recent challenges, often discussing the change in seagrasses to evaluate the Bay’s response to chronic and acute stressors. Seagrass cover in Tampa Bay has changed dramatically over time showing an increase over the last several decades, a recent decline from 2016 to present, and potential changes before and after the discharge from Piney Point in 2021. Discuss what factors control seagrass growth in Tampa Bay and how conventional approaches to environmental management have leveraged these factors to improve conditions in the Bay for seagrass recovery. How do these approaches compare for long-term management or in response to acute stressor events like Piney Point?
2. The ability of environmental managers to respond to changes in the Bay and document the impacts throughout 2021 was a demonstration of the value of past partnerships in the region. The Tampa Bay Estuary Program (TBEP) was fundamental to this effort. Discuss the role of the TBEP and its partners in coordinating a response to the Piney Point event. What type of information was collected and why was it important for understanding impacts to the Bay? How did the rapid response benefit from past partnerships and relationships? How can other regional management programs learn from these examples to improve their own response to similar events?
3. Central Florida has been a global headquarters for the extraction and production of fertilizer. What geological characteristics make this area favorable for fertilizer production? Discuss the challenges of fertilizer production that make it problematic for the environment. Why are gypstacks created and what makes them difficult to manage from an environmental perspective? Are there any alternative solutions you can think of for minimizing long-term harm on the environment from these facilities? Do you feel that the economic benefits justify continued fertilizer production relative to the impacts from Piney Point and other facilities in the region?
4. Do you agree with the statement “Piney Point was a disaster waiting to happen”? Why or why not? Describe the history of Piney Point and key decisions that led to the state of the facility in 2021. Where and when do you think critical decisions were made or not made that contributed to the ultimate decision to release wastewater into Tampa Bay? Make sure to identify the key players involved in these decisions and what entity they represent that could influence their choices on factors contributing to the events of 2021. Do you think any one party was to blame? How can more proactive measures be taken in the future to prevent similar events from occurring?

### 3.2 Individual student responses

1. Examine the trends in water quality parameters in [Figure 2](#fig-wqchange). Develop a narrative for how water quality changes influenced the ecology of Tampa Bay from April to September 2021, including how characteristics of the wastewater had cascading effects on other aspects of Tampa Bay. Link these changes to trends you observe in [Figure 3](#fig-fishkill) and [Figure 4](#fig-seagrasschange).
2. Given what you’ve learned about the long-term recovery in Tampa Bay, do you think the Bay would have responded differently to a large wastewater release from Piney Point if a similar event had occurred 40 years ago? Which environmental resources of the Bay would most be at risk compared to today?
3. Nutrient sources to surface waters are often described as point or non-point. Point sources of nutrients have declined in Tampa Bay whereas non-point sources continue to increase. What mechanisms have been used historically to effectively control point sources of nutrients? How would these approaches differ from controls on non-point sources? Consider identifying specific sources and evaluate strategies in other regions that have been successful.
4. Many options were considered to process and remove wastewater from Piney Point as part of the long-term closure plan. Ultimately, deep-well injection was chosen as the preferred method. Conduct a short literature review of this method for wastewater disposal to identify the risks and benefits relative to other methods.
5. In addition to long-term closure, several entities were required to provide monetary compensation as a result of the impacts to Tampa Bay from the 2021 wastewater discharge. Identify similar cases in the past where environmental disasters have led to financial compensation to remediate impacts. Based on these past studies, do you feel the compensation for Piney Point was sufficient relative to the impacts that were observed?
6. Environmental managers must consider multiple factors that influence environmental health and how they can be effectively monitored and controlled for long-term sustainability of natural resources. Piney Point is only one example of an external threat to Tampa Bay that requires management to reduce environmental impacts. What other factors in the Tampa Bay region must managers consider for protecting water quality?

## 4 Conclusion (500-1000 words)

This chapter provided an in-depth summary of factors influencing the decision to release 215 million gallons of wastewater from Piney Point, and how that release negatively affected the natural resources of Tampa Bay. This decision and its impacts were provided in the context of the history of the Piney Point facility and the long-term recovery of Tampa Bay over several decades. Overall, a narrative of environmental management was provided that highlighted the importance of partnerships and collaboration in the region to respond to acute stressors. Presently, the ecology of Tampa Bay has largely recovered from the events of 2021, and the long-term closure of Piney Point is ongoing. The TBEP continues to act as a facilitator for Bay management by bringing together public and private partners to collectively monitor and protect the health of Tampa Bay. A fundamental focus remains on the control of external sources of nitrogen that can degrade water quality and seagrass habitat. In particular, the TBNMC continues to track total nitrogen loads to the Bay, with representatives from dozens of regulated and regulatory entities in the region. Of note is the participation of Mosaic Co., the last remaining major mining interest in the region that has been and will continue to be a part of the TBNMC. Mosaic Co. is currently responsible for all active mines and gypstack closures in the Bone Valley, including mitigation of any future impacts to the Bay. Adoption of more concrete plans for the permanent closure of inactive phosphate mining sites, particularly plans that consider deep-well injection, is recognition that unintended wastewater releases into surface waters is a far worse outcome than inaction or adopting plans with some level of risk. The public may be ready to accept the risks associated with deep-well injection as a more desirable alternative than emergency release to the environment.

Countless examples exist worldwide that demonstrate the tradeoffs of human use of natural resources and impacts on the environment. For centuries, these tradeoffs often favored societal and economic gain at the expense of the environment. Shifts in public sentiment in the latter half of the 20th century brought widespread awareness to this imbalance, resulting in tighter regulation prompted by political action and societal concern to reconcile the complex relationships between our existence and environmental sustainability. The long-term recovery of Tampa Bay is one such example of how the population of Tampa Bay continues to grow while water quality is much improved from historical conditions when development and its impacts occurred unchecked. Despite this success, challenges still remain, and the events of 2021 further demonstrate the need for greater regulatory oversight and responsibility of regulated parties. In many cases, these challenges are not fully known or they are simply ignored until significant harm has already been done to the environment. Environmental management and regulatory oversight are more effective if actions are taken proactively rather than in reaction to events that cause harm to natural resources. However, proactive management is not possible unless all parties with vested interests in environmental health, including those that are sources of pollution, work together for a common good. Development and resource use cannot occur unabated and it is in everyone’s best interest to responsibly balance societal needs with environmental health, whether in Tampa Bay or elsewhere.

## Figures

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| Fig. 1: The Tampa Bay watershed and Piney Point. Bay segments, holding ponds, and other relevant locations are shown. County boundaries are labeled with paired county names. NGS-N: New Gypsum Stack North; NGS-S: New Gypsum Stack South; OGS-N: Old Gypsum Stack North; OGS-S: Old Gypsum Stack South. Basemap credits: Esri, HERE, Garmin, OpenStreetMap, Maxar, and Earthstar Geographics. |

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| Fig. 2: Water quality changes from March to September 2021 near Port Manatee at the discharge point. Monitoring data are shown for (a) total nitrogen for nutrients, (b) chlorophyll-a as an indicator of algal production, and (c) Secchi depth as a measure of water clarity. Monthly baseline ranges are shown in blue as an estimate of normal conditions from the past fifteen years. Notable algal bloom events as shown by increases in chlorophyll-a are shown in (b). Data sources described in Beck et al. (2022). |

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| Fig. 3: Fish kill reports for Hillsborough, Manatee, and Pinellas Counties that border Tampa Bay. Plot (a) shows reports by year and plot (b) shows reports by week for 2021. Data from Florida Fish and Wildlife Commission fish kill hotline. |

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| Fig. 4: Seagrass change from 2020 to 2022 for selected seagrass management areas identified by the Tampa Bay Estuary Program. Map (a) shows the overall acreage change by management area and map (b) shows the areas where seagrass was lost or gained. See [Figure 1](#fig-map) for the locational context. Data from the Southwest Florida Water Management District. |

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| Fig. 5: Progress to date closing the NGS-S holding pond at Piney Point. The top plot shows the volume of water in the pond and the bottom plot shows the overall capacity of Piney Point to accommodate additional stormwater, inclusive of the volume of water onsite and rainfall. Key events affecting the closure process are shown by the horizontal lines. Data from the Florida Department of Environmental Protection. |

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