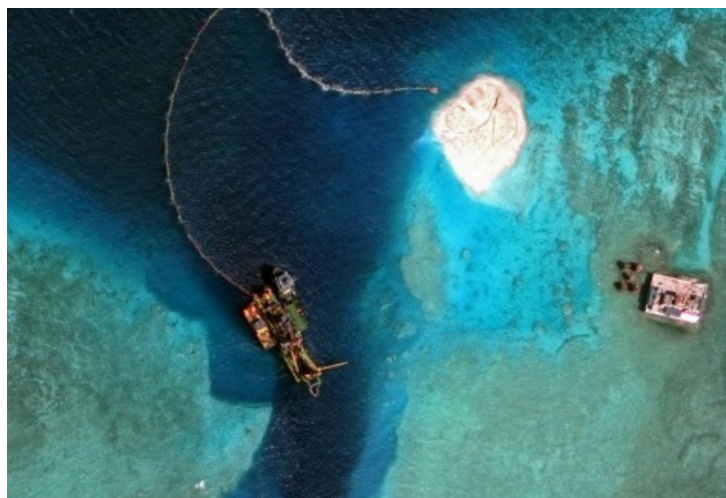


Sand Wars

Beijing's Hidden Ambition in the South China Sea

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Rapid urbanization has accelerated the demand for raw materials in China. Sand, in particular, is critical to the production of concrete—but it is also a nonrenewable and increasingly scarce resource. Beijing now seeks sand from its Southeast Asian neighbors, but many of these governments have banned sand exports due to environmental concerns. With limited options, China will likely look to the South China Sea (SCS) not only to access oil and natural gas, but also sand. Although the United States seeks to mitigate regional disputes over sovereignty and energy resources, current policy overlooks sand as a source of tension. Washington should prioritize sand in SCS negotiations and use access to research and development of manufactured sand as leverage against aggressive Chinese behavior.

Introduction

U.S. policy towards the Asia Pacific overlooks how sand may influence regional security dynamics. Sand, an essential component of concrete, has become a highly sought-after commodity in Asia because infrastructure development is critical to economic growth. Pressures on sand resources have grown exponentially over the past three decades, especially due to rapid urbanization in China. However, finite inland resources cannot sustain China's demand. The scarcity of sand will spark a competition for deposits in the South China Sea (SCS) among stakeholders, including Indonesia, Malaysia, and Vietnam, and jeopardize security in a region already prone to conflict. Beijing's aggressive pursuit of marine sand resources will likely contribute to regional tensions and reduce Washington's capacity to achieve strategic goals.

Current U.S. policy towards the region seeks to promote trade and investment, strengthen security alliances, and improve environmental security. Economic well-being in Asia is intimately tied to the vitality of U.S. trade, but a competition for sand in the SCS could disrupt gains from initiatives such as the Trans-Pacific Partnership (TPP).¹ China's growing presence in the SCS also challenges U.S. influence in the region. Specifically, Beijing's recent island-building campaign and missile deployment may undermine U.S. security commitments to increasingly important regional allies.² Moreover, dredging in the SCS will severely endanger environmental security in the Asia Pacific.³ To manage existing disputes over sovereignty and energy resources in the SCS effectively, the United States can no longer ignore sand as a potential driver of conflict.

China's Insatiable Demand for Sand

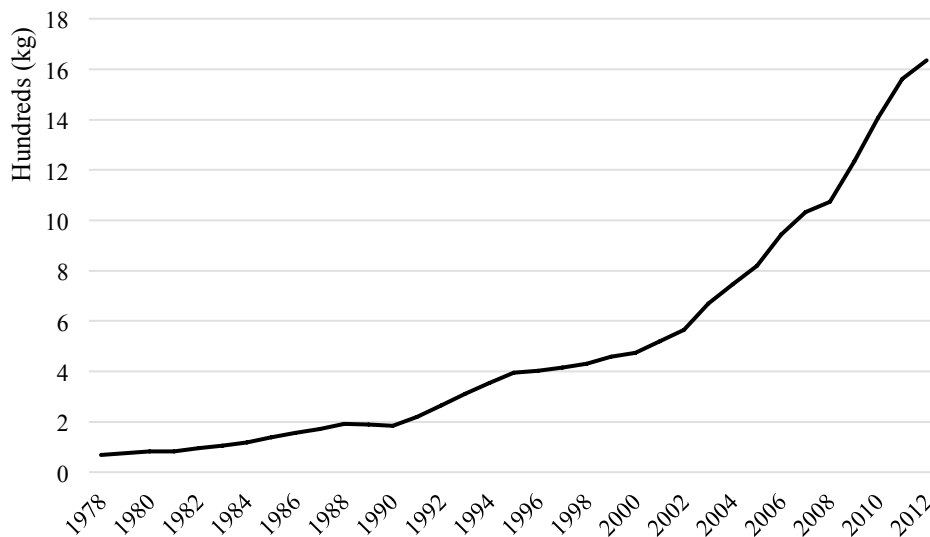
Sand is one of the world's most highly-coveted commodities and is mined extensively as a construction material. Mixed with water, cement, and gravel, sand is used as a fine aggregate in the production of concrete.⁴ Rapid economic growth in Asia drives global demand, straining supplies of a nonrenewable resource. According to the United Nations Environment Programme,

global consumption of concrete aggregates exceeds 40 billion tons annually, which is twice the amount of sediment transported by all rivers worldwide every year.⁵ As natural sand deposits are increasingly depleted from inland rivers and lakes, the demand for fine aggregate will exceed available supply. Population growth and urbanization in China, especially, will place increased pressures on sand resources.

Urbanization in China

Due to an unprecedented rate of urbanization over the past three decades, China currently occupies the largest market for concrete aggregate in the world.⁶ In the next 15 years, China’s urban population is expected to grow to one billion.⁷ The Chinese Communist Party (CCP) aims to increase the urban share of the population to 60 percent by 2020, which will necessitate a major physical build-out of Chinese cities over the next few decades.⁸ In 2015, China’s National Development and Reform Commission approved plans for over 1,000 mega-infrastructure projects.⁹ Rapid construction will facilitate accommodations for up to 3.4 billion people in its sprawling urban areas.¹⁰ As Chinese cities continue to expand, concrete production for infrastructure development will require increasing quantities of sand.

Figure 1. Chinese Cement Production (per capita)



Source: National Bureau of Statistics of China

In 2013, China’s demand for construction-grade sand reached approximately four billion metric tons.¹¹ Cement and concrete can also provide proxies for aggregate demand (see Figure 1). For example, cement consumption in China increased by 437.5 percent in the past 20 years, whereas use in the rest of the world increased by 59.8 percent.¹² China also used more concrete over three years (2011-2013) than the United States used throughout the entirety of the twentieth century.¹³ Recent trends indicate that China’s demand for construction materials is not likely to diminish

over time, despite a slowing economy. China's economic downturn may cause growth rates in sand consumption to fall slightly. In absolute terms, however, massive gains are expected. Demand for concrete aggregates reached 9.25 billion metric tons in 2013, and is projected to increase to 27.50 billion metric tons by 2020.¹⁴

The Scarcity of Sand

Natural sand, which weathers over thousands of years, is a nonrenewable resource. Rock breaks down into small particles that are subject to prolonged transport in water and accumulate downstream in riverbeds, deltas, and coastlines. Sand derived from in-stream sources is preferred for fine aggregate, because its rounded shape and smooth texture requires minimal processing to produce high-quality concrete.¹⁵ As such, natural sand is used extensively in construction activities.¹⁶ Because large quantities of sand are extracted from inland sources, consumption far exceeds the rate of renewal in many parts of the world.

As demand for concrete aggregate continues to grow, China's finite resources are rapidly diminishing. Dredging inland to procure fine aggregate is unsustainable, and the removal of sediment from rivers and lakes causes a variety of environmental and socio-economic problems, including flood risk, water shortage, and degradation of aquatic ecosystems.¹⁷ Extensive sand mining since the mid-1980s has exhausted many of China's vital supply sources, including the Poyang Lake and the Pearl and Yangtze rivers.¹⁸ In a measure to preserve domestic supplies, Beijing banned exports of sand in 2007.¹⁹ Protective policies, however, have not alleviated sand shortages within China's borders. For example, the annual demand for sand in Guangdong Province reached 100 million tons in 2012, yet local and regional stocks only delivered 14 million.²⁰ As the gap between supply and demand widens, China's construction industry must look elsewhere for sources of fine concrete aggregate.

Economic Growth Contingent on Sand Supply

A country's economic growth is often linked to the exuberance of its construction industry, and by extension, inputs of fine concrete aggregate.²¹ Concrete is a necessary requisite for infrastructure vital to economic growth. To recover from a sluggish economy, the Chinese government has sought to boost domestic construction activity.²² For example, Chinese Premier Li Keqiang emphasized urbanization as central to the country's economic development, and advocated a fixed asset investment-led growth model to revive high growth rates.²³ The "build-it-and-they-will-come" approach is based on state-led funding for roads, highways, and other infrastructure to support industrial activity.²⁴ For example, China's National New-Type Urbanization Plan for 2014-2020 aims to relocate a several 100 million people to cities in an effort to stimulate economic growth.²⁵

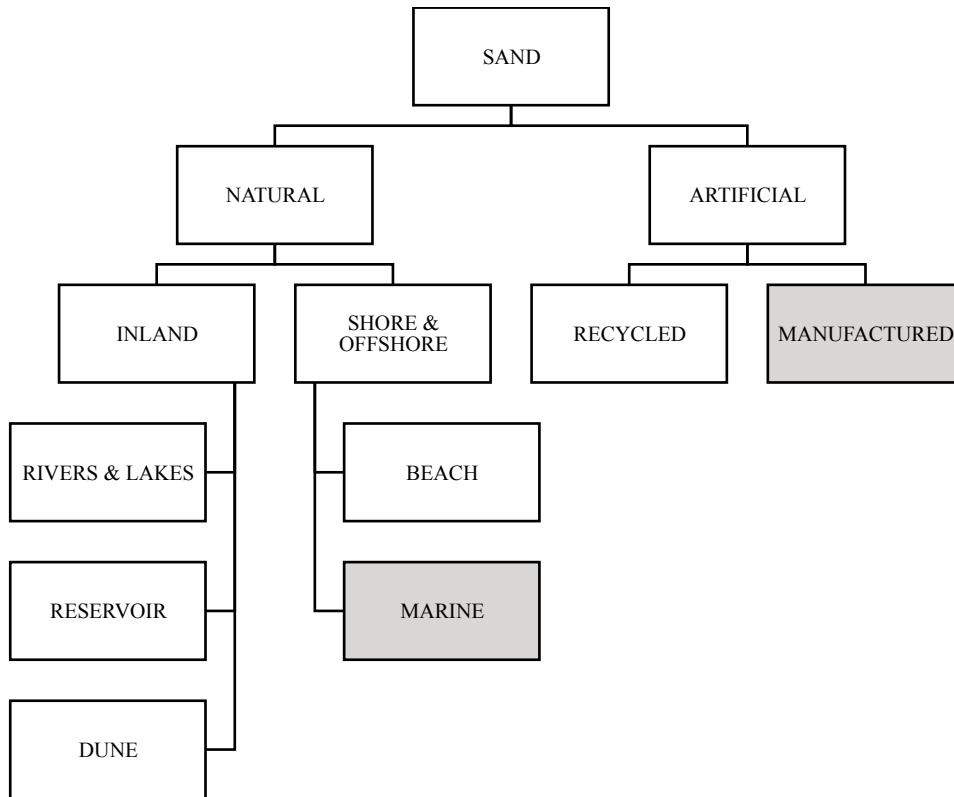
The CCP may perceive continued economic growth as dependent upon access to cheap and plentiful sand. However, diminishing inland sources will hinder efforts to revitalize the Chinese economy through infrastructure development. As such, expanding and diversifying sand resources has become an increasing priority for the CCP.

Alternatives to Fine Concrete Aggregate

Until recently, China has relied on sand from riverbeds and lakes for concrete production, but declining inland resources necessitates alternate sources of fine aggregate. Moreover, regional trade in natural sand has become increasingly restricted in recent years. Although China was the world's top importer of concrete aggregates between 2011 and 2014, the governments of Cambodia, Indonesia, and Vietnam have recently banned sand exports for environmental reasons.²⁶ Specifically, China's high trade volumes drive sand mining operations in neighboring countries that often accelerate coastal erosion, destroy aquatic ecosystems, and reduce resilience to climate change.

With constraints on both traditional inland sources and regional trade, China will seek potential substitutes for fine concrete aggregate (see Figure 2). Both natural and artificial alternatives to river and lake sand are available, but many of these are not sufficient in structural applications (see Appendix A). For example, dune sand taken from desert sources does not bind well in concrete mix and may only compose a small percentage of aggregate.²⁷ Similarly, recycled sand may only be used at a ratio of 20 to 30 percent.²⁸ Dredging sand from beaches is problematic due to coastal erosion and is an illegal practice in China.²⁹ Crushed stone and offshore marine sand deposits present the most viable substitutes for fine aggregate, although each of these are not without limitations.

Figure 2. Sources of Fine Concrete Aggregate



Artificially Manufactured Sand

Fine concrete aggregate may be produced artificially by crushing stone to a standard size.³⁰ Manmade sand is expected to gain market share as the country's inland rivers and lakes are further depleted, although natural sand remains the most highly consumed construction aggregate in China.³¹ Manufactured sand is a promising substitute for fine concrete aggregate, but has not yet gained a strong foothold in Asia. Specifically, the use of crushed stone in concrete mix is not commonly accepted in China's construction industry for the following reasons:³²

- *Inconsistent quality across localities.* While rock quarries are relatively abundant, unfavorable geographic distribution may limit the availability of quality material near the site of construction.³³ Often, crushed stone must be blended with natural sand to achieve appropriate grading and workability.³⁴ Moreover, urban encroachment and land-use conflicts result in local shortages, raising prices for crushed stone suitable for concrete production.³⁵ Concrete made with crushed stone is also costly because it requires more cement to account for its poor shape.
- *High cost of production and transport.* Although access to Chinese data is limited, U.S. prices for concrete aggregate are available. In the United States, crushed stone currently sells for 10.46 USD per metric ton, whereas natural sand sells for only 7.72 USD.³⁶ Crushing, screening, and washing quarried rock is an added expense that is reflected in the relatively high price of manufactured sand. Transportation costs are also significant. Proximity to local markets is key, and most aggregates are not shipped further than 35 to 50 miles from where they are excavated.³⁷ Otherwise, the cost of transport may exceed that of the material itself.³⁸ Especially with increased migration to urban centers in China, quarries near the site of construction undergo more rapid rates of depletion.³⁹
- *Insufficient supply to meet market demand.* Manufactured sand that is produced from quality material and processed appropriately may act as a perfect substitute for natural sand in concrete. However, if crushed stone is indeed used as a total replacement for fine aggregate, most rock quarries would only be capable of meeting 30 to 50 percent of market demand.⁴⁰ Switching costs also provide a barrier to adaptation. The construction industry is relatively conservative and risk-adverse, and as such, is reluctant to change well-known practices to accommodate new materials in concrete production.⁴¹

While there is a trend towards artificially produced sand in Asia, natural sand will remain popular due to its lower price.⁴² As of yet, Japan is the only country in Asia that has managed a successful transition to manufactured sand. In 1990, Tokyo banned all dredging activities to preserve the country's extremely limited natural resources.⁴³ The Japanese government strongly supports the research and development of crushed stone as an alternative source of concrete aggregate. Similar progress throughout Asia, however, is stagnant due to a continued dependence on natural sand.

Offshore Sand Deposits

High prices will curb demand for crushed stone in China. Marine sand, on the other hand, offers one of the cheapest forms of fine concrete aggregate, particularly because vast quantities exist beyond China's coastline.⁴⁴ Presently, marine sand is available at approximately half the price of river and lake sand in China.⁴⁵ Although the cost to process and transport marine sand may provide additional burdens, these expenses are either circumvented or offset in the Chinese market:

- *Poorly regulated construction industry in China.* Marine sand contains chlorides, which cause corrosion in steel. Over a period of 25 to 30 years, structural damage may render buildings at risk of collapse.⁴⁶ If washed to remove chloride, marine sand that meets standard size may reliably contribute up to 100 percent of fine concrete aggregate—although this is an expensive process because of the amount of water required.⁴⁷

Despite the hazards of using raw marine sources for fine aggregate, Chinese builders have demonstrated a willingness to sacrifice quality—risking long-term structural integrity—to reduce short-term costs.⁴⁸ In 2013, the government of Shenzhen discovered that at least 31 companies had used unprocessed sea sand in major construction projects throughout the city, including one building that is projected to become the tallest in China.⁴⁹

- *Economies of scale offset cost of shipping.* Local markets are generally preferred because it can be expensive to source sand far from the site of construction. As economies of scale come into play, however, marine sand dredging will become increasingly profitable, especially because the cost to ship sand over water is approximately one-third less than over land.⁵⁰ The use of marine sand is also economical for China's geographic distribution because many of the country's growing cities are situated on or near the country's coast.⁵¹ Accordingly, marine sand is already widely used in construction throughout China's coastal areas.⁵²

With only a few viable substitutes for fine concrete aggregate available, marine sources have been increasingly exploited to supplement China's dwindling local supplies. Despite processing and transportation costs, marine sand is preferred to other alternatives because it is relatively cheap and readily available. Marine sand may also serve as a full replacement for fine aggregate to effectively meet China's rising demand, which will likely lead to active investigation and exploitation of deposits in the SCS.⁵³

Competition for Sand in the SCS

As marine sand becomes a more attractive means to satisfy China's growing demand for construction-grade aggregate, there will be more at stake in the SCS beyond energy resources. Beijing is already constructing artificial islands reinforced with airstrips and missiles to assert its

sovereignty over the SCS. China may take similar measures to gain access to sand on the seabed of the SCS, possibly escalating regional tensions.

Sand Scarcity and Existing Regional Disputes

Efforts to guarantee unimpeded access to sand in the SCS may exacerbate disputes over sovereignty. Beijing lays claim to roughly 90 percent of the SCS, and asserts its right to explore those waters for natural gas and oil reserves.⁵⁴ Overlapping claims to sovereignty have strained relations among regional stakeholders, and China's aggressive pursuit of sand will further complicate ongoing disputes. To preserve access to sand resources in the SCS, Indonesia, Malaysia, and Vietnam may seek to fortify claims to sovereignty based on the provisions of the United Nations Conventions on the Law of the Sea (UNCLOS).

Whereas oil and natural gas are not proven to exist in the SCS, vast quantities of sand certainly do. Sand scarcity provides an additional incentive for China to assert its sovereignty over the SCS, which will likely exacerbate regional tensions. Beijing may choose to defy regulations delineated in UNCLOS that would otherwise prohibit access to deposits existing beyond China's exclusive economic zone.⁵⁵ As sand becomes an increasingly critical resource, Beijing is far less likely to relinquish its claims over the SCS. China's growing demand for concrete aggregate may severely hinder any progress towards peaceful settlement of existing disputes.

China's Advanced Dredging Fleet

China has already developed the capacity for large-scale dredging in the SCS and may redirect its island-building efforts to benefit the country's construction industry. Over the past 15 years, Beijing's dredging operations have drastically outpaced those of other states in the region. China has assembled a large fleet of sea-going vessels that can pump material directly from the ocean floor. For example, the specialized dredger *Tianjing* is Asia's largest and can move over 100,000 cubic meters of sand every day.⁵⁶ The country's annual dredging volume more than tripled over an over an eight-year period from 300 million cubic meters in 2001 to one billion cubic meters in 2009.⁵⁷

Having developed larger and more sophisticated dredging equipment to operate at faster speeds and greater depths, China now employs these machines in a variety of different settings.⁵⁸ In Beijing's controversial island-building projects, vessels extract sediment from the seafloor, then pile sand onto reefs to create artificial landmass.⁵⁹ Recent advancements in dredging techniques and technologies have also been directed towards the production of concrete aggregate for national infrastructure projects.⁶⁰ For example, a state-owned infrastructure group, the China Communications Construction Company, claims over half of the nation's dredging capacity.⁶¹ Another, the China State Construction and Engineering Company is known to have used marine sand in infrastructure development.⁶²

Bolstered capacity will facilitate China's pursuit of both hydrocarbon and nonfuel resources in the SCS. Beijing may threaten freedom of navigation to ensure that its own dredgers have uninterrupted access to a much needed source of sand. As China's demand for concrete

aggregate increases, Beijing will likely challenge other stakeholders in the SCS and alter regional security dynamics.

The Effect of Instability in the SCS on U.S. Security

China's potentially aggressive pursuit of sand presents another challenge to U.S. strategic interests in the Asia-Pacific region. A competition for sand in the SCS would disrupt significant trade flows and strain relations with increasingly important security partners. Unrestrained dredging activity may also endanger environmental security and undermine key U.S. allies in the region.

Disrupted Trade Flows

Sand competition threatens freedom of navigation in the Asia Pacific. More than 40 percent of global trade flows through the SCS, with U.S. trade amounting to \$1.2 trillion annually.⁶³ Secure sea lines of communication (SLOCs) ensure open economic access to the United States and its trade partners, but China's aggressive approach to the SCS could disrupt trade routes through strategic chokepoints. The Strait of Malacca is particularly important, as many U.S. allies in the Asia Pacific depend upon the energy resources transiting that waterway.

With China having recently superseded the United States as the largest trading nation in the world, Washington is wary that Beijing's growing economic influence might obstruct access to the burgeoning markets of the Asia Pacific. The TPP would allow the United States to take advantage of the region's growing consumer base, and the Obama Administration has promoted the trade agreement as an alternative to the China-led Asian Infrastructure Investment Bank.⁶⁴ However, the TPP is not likely to gain the upper-hand if regional trade is interrupted by disputes in the SCS.

Weakened Security Alliances

China's growing presence in the SCS challenges the role of the United States in the Asia Pacific. The Obama Administration's "pivot" to Asia aims to counter China's mounting regional influence, particularly by strengthening security ties with countries such as Indonesia, Malaysia, and Vietnam.⁶⁵ Meanwhile, China is also revamping its relations with ASEAN member states. For example, Beijing has advocated for an "Asian" dispute settlement mechanism that excludes outside powers, including the United States.⁶⁶ China also proposed a joint training on the Code for Unalerted Encounters at Sea (CUES) in the same month that a U.S. warship sailed through disputed waters to repudiate Chinese claims.⁶⁷ An emerging blue water naval power, China is also making huge diplomatic gains at the expense of U.S. influence. To preserve its leadership role in the Asia Pacific, the United States must demonstrate a firm commitment to the security interests of its regional partners.⁶⁸ As such, Washington seeks to empower allied states to rebuff aggressive behavior in the SCS.

Endangered Marine Environments

Diminishing sand resources may also frustrate Washington's efforts to mitigate environmental insecurities in the Asia Pacific. Dredging has significant consequences for marine environments, including a negative impact on biodiversity, increased coastal erosion, and heightened levels of pollution (see Appendix B).⁶⁹ Especially for small countries and island states, offshore mining activities exacerbate existing environmental challenges. For example, Indonesia's environmental problems are compounded by sand dredging operations. While the country's exterior islands serve as a buffer zone against storms and tsunamis, the deterioration of 24 small islands due to the overexploitation of sand resources has further reduced Indonesia's resilience to climate change.⁷⁰ Moreover, offshore fishing provides a major source of protein for many of the populations of Southeast Asia. Dredging in the SCS significantly reduces fish stocks in those waters.⁷¹ As such, marine sand excavation presents a serious threat to the livelihood of key U.S. allies in the Asia Pacific.

U.S. strategic interests are increasingly at stake as a competition for sand aggravates existing tensions in the Asia Pacific. Despite the prevalent threat of sand scarcity to U.S. influence, current policy fails to encompass sand into its perception of regional security dynamics. To effectively resolve regional disputes, American policymakers must address the issue of sand scarcity sooner rather than later.

A Blind Spot in Current U.S. Policy

China is out of step with both the international rules and norms that underscore the Asia-Pacific's security architecture, and the regional consensus that favors diplomacy and opposes coercion.

– Ash Carter, U.S. Secretary of Defense, 2015⁷²

Until recently, the United States has taken a passive approach towards the SCS.⁷³ However, Beijing's island-building campaign has prompted a revision of U.S. policy. Washington now openly challenges China's claims to sovereignty in the SCS and is taking a more active role in negotiations to mitigate risk of regional conflict. Thus far, uncooperative Chinese behavior has obstructed progress towards peaceful resolution of existing disputes over sovereignty. Sand scarcity poses yet another threat to regional peace. As China's dependence on marine sand resources continues to grow, Beijing will become ever more reluctant to relinquish its foothold in the SCS.

Current U.S. policy ignores sand as a potential source of conflict and thereby underestimates Beijing's resolve to control the SCS. Such oversights will hinder Washington's efforts to enhance regional security. The United States must acknowledge that an emerging competition for sand will complicate ongoing negotiations and diplomatic exchanges. In failing to recognize the importance of sand in shaping regional security dynamics, Washington lacks a comprehensive approach towards the SCS. So long as sand is at stake, the United States and its

allies will face difficulty in shaping Chinese behavior in the SCS. To more effectively restrain Chinese aggression, U.S. policy must address all facets of existing disputes, including sand.

The United States must prioritize sand in SCS policy to ensure a comprehensive approach towards regional peace. Washington should also take advantage of sand scarcity as an opportunity to exploit an unrecognized Chinese vulnerability. Using sand as a leverage, the United States can incentivize China to abide by international norms and engage in multilateral negotiations.

Policy Recommendation: Sand Diplomacy

The United States should regard sand as a strategic material that may be used as a leverage to influence security dynamics in the Asia Pacific. To effectively manage disputes in the SCS, the United States should enact policy that (1) factors sand into Washington's diplomatic calculus and (2) uses the research and development (R&D) of manufactured sand to influence Chinese behavior. The United States can implement sand diplomacy not only to reduce the threat of sand competition, but also to address broader regional disputes.

Prioritize Sand in SCS Negotiating Strategies

Currently, the United States promotes a collaborative approach to reduce the risk of conflict in the SCS, and prioritizes international rules and norms as a basis to reach peaceful settlement.⁷⁴ According to the U.S. Department of Defense, the complex nature of the SCS disputes requires a "coordinated multilateral response" to build trust between China and its neighbors.⁷⁵ However, Washington's emphasis on multilateral mechanisms is incompatible with Beijing's preference for bilateral tracks. Because China is reluctant to participate in multilateral forums, diplomatic efforts to halt land reclamation and militarization have been largely unsuccessful thus far.⁷⁶ Recognizing sand scarcity as an emerging Chinese vulnerability, the United States can implement "sand diplomacy," a new approach to SCS negotiations, to facilitate dispute management and enhance regional maritime security.

Using sand as a bargaining chip, Washington can draw Beijing towards constructive dialogue between all stakeholders in the SCS. To do so, the United States should support its regional allies in a shift towards crushed stone as a strategic source of concrete aggregate. Sand that is artificially produced in Indonesia, Malaysia, and Vietnam may be used to supplement China's supply. With the research and development of manufactured sand, these Asian countries can achieve lower production costs for higher-quality material. If offered an attractive alternative to fine concrete aggregate, Beijing will be more likely to participate in multilateral negotiations. Alternatively, the United States can use sand as a check against Chinese aggression. For example, Washington can encourage its allies to restrict exports of manufactured sand in response to hostile behavior. Beijing will likely prefer not to risk its access to sand produced in neighboring countries. In this way, sand diplomacy is a multipurpose tool that can either incentivize cooperation or dissuade aggression in the SCS.

Support R&D of Manufactured Sand in Asia

Manufactured sand is a well-established substitute for fine concrete aggregate in the U.S. construction industry, partly because local firms have adapted readily to the use of artificial material in concrete production.⁷⁷ Over half of construction aggregates used in the United States are crushed stone, whereas the production of manufactured sand is minimal in countries such as Indonesia, Malaysia, and Vietnam. U.S. civil engineers and construction industry experts should advise their counterparts in Southeast Asia to promote advancements in the method, equipment, and regulation of manufactured sand production.

- *Improve methodology to identify suitable resources.* The U.S. Geological Survey is currently working with the Coordinating Committee for Geoscience Programmes in East and Southeast Asia to document the region's nonfuel resource endowments. The United States should expand upon this project to identify and analyze rock quarries in Asia with the potential to produce artificial sand.⁷⁸
- *Support technological improvements.* To manufacture sand that is competitive with marine deposits, Southeast Asian allies will require U.S. support to research new methods to achieve standards of shape and size that would minimize more expensive components of concrete mix, such as water and cement. Switching from natural to manufactured sand may also incur added costs. To facilitate the adoption of artificially produced concrete aggregate, the United States should support necessary changes to overall project design.
- *Establish industry regulations.* Well-defined guidelines for the production of manufactured sand will allow for sustainable use in Asia.⁷⁹ To maximize economic value while minimizing social and environmental impacts, the United States can provide integrated software for permitting, reserve calculations, mine design and operation, stockpile management, and reclamation.⁸⁰

Washington can promote artificially-produced sand as the dominant choice for concrete aggregate in Asia, increasing its market share to reduce regional dependence on natural sources. By doing so, the United States and its allies in the Asia Pacific can incentivize China to pursue manufactured sand available from regional suppliers, rather than outsourcing for sand in the SCS. As crushed stone is further developed as an alternative to natural sand, costs will fall and China will prefer to import high-quality artificial sand than to dredge for marine sand of lower quality.

Conclusion

As China's construction industry continues to expand, Beijing will require alternate sources of sand for use as concrete aggregate. This paper explores the potential for sand scarcity to aggravate tensions in the SCS, possibly threatening key U.S. interests and altering regional security dynamics. American policymakers should acknowledge the severity of sand scarcity in the Asia Pacific and implement sand as a tool in SCS negotiations to influence Beijing's

behavior. While sand can produce a serious challenge in the SCS, it can also act as its own solution.

Policy analysts should also consider how the demand for concrete aggregate, and sand in particular, will influence security dynamics in other areas. For example, China may also look to the East China Sea to satisfy its rising demand, where its rivals for sand may include South Korea and Taiwan. Competition for sand in the Indian Ocean may also emerge between Beijing and Delhi. India's population is expected to surpass that of China as early as 2022.⁸¹ Facing similar domestic pressures, Delhi may turn to the Indian Ocean for marine sand deposits. Simultaneously, Beijing may require sand from the Indian Ocean to support massive infrastructure projects along critical maritime trade routes.⁸² A desperate pursuit of sand may place China at odds with regional stakeholders even beyond the SCS.

Appendix A. Alternate Sources of Fine Concrete Aggregate

	Advantages	Disadvantages
Reservoir Sand	<ul style="list-style-type: none"> • Viable source of building material. • Trapped sediment may be easily excavated upstream.⁸³ 	<ul style="list-style-type: none"> • Sand accumulation causes sediment load in water released downstream to decrease.⁸⁴
Dune Sand	<ul style="list-style-type: none"> • Widely available in some regions, such as the northern Gobi Desert. 	<ul style="list-style-type: none"> • May only be used for up to 20-30 percent of fine aggregate.⁸⁵ • Produces grains that are fine, single-sized, and poorly graded. • Does not bind well; compromises strength in concrete.
Recycled Materials	<ul style="list-style-type: none"> • Many of China’s new cities (“ghost cities”) are uninhabited due to poor urban planning, so material is widely available. 	<ul style="list-style-type: none"> • Material salvaged from vacant structures may only replace natural sand at a substitution ratio of up to 30 percent.⁸⁶ • High water-absorption ratios result in poor durability.
Beach Sand	<ul style="list-style-type: none"> • Available in abundant quantities on China’s coast. • Proximity to urban centers reduces transport costs. • Provides quality material if washed to remove corrosive chloride. 	<ul style="list-style-type: none"> • Dredging for coastal sand sources is prohibited by China’s Marine Environment Protection Law.⁸⁷ • Causes devastating erosion of the shoreline. • Washing is a costly process.

Appendix B. Environmental Impacts of Offshore Dredging

Biodiversity Loss	<ul style="list-style-type: none">• Destroys marine organisms and habitats that are crucial components of the food chain (i.e. coral reefs and fish nurseries).• Diminishes net biomass of seabed flora and fauna.⁸⁸
Poor Water Quality	<ul style="list-style-type: none">• Increases water turbidity.⁸⁹• Releases toxic chemicals, harmful metals, and dredged waste that contaminates water.
Coastal Erosion	<ul style="list-style-type: none">• Reduces sediment from the sea floor.• Impedes shoreward drift.⁹⁰

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- ¹ U.S. Department of State, “Strategic Goal 2: Objective 2.2 - Rebalance to the Asia-Pacific through Enhanced Diplomacy, Security Cooperation, and Development,” *FY 2014-2017 Department of State and USAID Strategic Plan*, <http://www.state.gov/s/d/rm/rls/dosstrat/2014/html/225797.htm> (accessed January 25, 2016).
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