

LIMITING
THE
AFTERMATH:
VOLCANIC
APOCALYPSE

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INTRODUCTION

Throughout history, humankind has pursued security: from fellow human, from beast, and from nature itself. The third of these foes has proven itself the most resilient to the wit of our species. Despite innumerable deadly assaults on communities around the world, we have been consistently underprepared for the threat of our environment, from hurricanes to tsunamis to perhaps the most fearsome of all: volcanic eruptions. In 1815, the largest blast in recorded history took place at Mt. Tambora, Indonesia. Beyond the immediate terror of the eruption, the long term outcomes were devastating. The eruption hurled thousands of tons of ash into the atmosphere, which caused average temperatures to fall by 1 to 2.5 degrees. The “Year Without a Summer” which ensued led to serious famines as crops and livestock were ruined by the change in climate.¹ So catastrophic and massive were these events that many at the time considered the eruption to be the wrath of Allah.²

The volcanic hotspot that is currently under the Yellowstone park region has produced three giant eruptions over the past few million years. The first occurred 2.1 million years ago, ejecting 600 cubic miles of material and hollowing out a crater larger than the state of Rhode Island. Around 1.3 million years ago the volcano erupted again. The smallest of the eruptions, this one was nonetheless a behemoth, measuring 700 times larger than the 1980 eruption of Mount St. Helens. Still mighty after the first two eruptions, Yellowstone’s most recent volcanic activity took place 630,000 years ago and created the current Yellowstone Caldera.³

When eruptions occur, they interfere with the productive capabilities of the affected areas. For unprepared communities, this can spell economic disaster, by destroying sources of income and interrupting modes of international trade. To quell these issues, international aid may be required to help cope with the crisis, even in a wealthy nation such as the United States. The average American household owes more than twice as much as they earn in a year. When disaster strikes, it will inhibit Americans’ ability to earn, but their debts will stand. This fearsome duo sets the

¹ Bernice De Jong Boers. "Mount Tambora in 1815: A Volcanic Eruption in Indonesia and Its Aftermath." *Indonesia*, no. 60 (1995): 37-60. doi:10.2307/3351140.

² Ibid.

³ "Questions about Yellowstone Volcanic History." U.S. Department of the Interior. Accessed August 4, 2018, 2018. https://volcanoes.usgs.gov/volcanoes/yellowstone/yellowstone_sub_page_54.html.

country up for a financial disaster unlike any in the history of modern America. Furthermore, volcanic activity on the scale of the previous Yellowstone eruptions would destroy infrastructure necessary for the use of survivors, as well as for relief missions. The immediate and long term damage to the climate caused by a Yellowstone eruption could spell disaster for the environment, wildlife, and communities surrounding it.

While research about volcanoes has come a long way, our gained knowledge has largely failed to tame them, as is true of many other environmental phenomena. At present, the scientific community can only hope to continue improving its understanding of their activity. That said, much of the responsibility for dealing with the consequences of volcanic eruption falls to rescue workers, public servants, and diplomats. These individuals have to deal with rescue efforts, but also with the realities of life after the disaster. Technological development may be the only hope to cope with food and water insecurity, as well as logistical issues posed by the destruction of infrastructure. Lastly, measures will need to be taken to ensure societal stability. Accommodating refugees, curtailing violence, and ensuring the protection of human rights are vital issues that stem from volcanic crises.

In the year 2020, officials from the United States Geological Survey (USGS) have detected concerning readings coming from the Yellowstone Caldera, with large lava flows and a noticeable swelling of the magma chamber underneath the caldera. Tourists and non-essential personnel are being evacuated from the immediate area. Volcanologists familiar with the situation fear that an eruption is imminent. The leaders of the G20 have arranged to meet to prepare the global community's course of action. Meanwhile, an emergency committee of the most significant U.S. government officials has been convened in order to prepare a domestic response to the upcoming crisis.

TOPIC 1

FOUNDATIONS

SECTION 1A:
ECONOMY

SECTION 1B:
INFRASTRUCTURE

SECTION 1A: ECONOMY

Background

In our conception of the impacts of a large scale disaster such as a volcanic eruption, the immediate havoc of the event typically stands tall above the other outcomes. However, relief efforts must account for how the widespread destruction from a Yellowstone volcano eruption would severely damage the economy of at least the area affected, but more likely of the world at large. Much of this damage would be to the industrial and service sector, which face the double threat of physical destruction paired with employee and customer evacuation.⁴ As a result the productive capabilities of the economy will be emaciated. This lack of productivity will of course be felt in other areas of the economy, as the population copes with mass job loss and reduced supply of goods. In all likelihood, the decline in output will manifest itself in rampant inflation and a decline in investment as well as in stock prices.

Introduction

The suffering brought on by financial disasters throughout Western history has been immense. Their long legacy of hunger and strife has scarred our collective memory. No better example exists than the Great Depression, which ravaged the world economy, especially in Europe and the United States. Beginning with the Stock Market Crash of 1929, the roaring economy of the 1920s disintegrated, leaving disease, homelessness and malnourishment in its wake. By 1933, nearly 30 percent of the workforce in the United States was unemployed.⁵ Only the large scale spending of World War Two, a decade later, was sufficient to lift the financial world from the rubble.

More recently, the financial disaster of 2008 resulted in mass bankruptcy and suffering in America and abroad. The crisis arose by way of banks giving out risky home loans referred to as subprime mortgages, for which repayment was highly unlikely. The Great Recession had a global impact, with the United States facing the worst of the damage. According to Robert Rich, America's real Gross Domestic Product (GDP) fell

⁴ Kliesen, L. Kevin. "The Economics of Natural Disasters." *Regional Economist* (April 1994, 1994): August 3, 2018.

⁵ History.com Staff. "Stock Market Crash of 1929." A+E Networks. Accessed August 3, 2018, . <https://www.history.com/topics/1929-stock-market-crash>.

by 4.3% in one and a half financial years.⁶ Similarly, the net worth of the country's nonprofit organizations and households combined fell from \$69 trillion in 2007 to \$55 trillion in 2009.⁷ The crisis, now referred to as the Great Recession, had an devastating impact which for some nations took nearly a decade to recover from.⁸

In the past, natural disasters have proven their ability to wreak serious economic havoc in their respective regions and countries. For example, the 2011 Tōhoku earthquake and subsequent tsunami cost Japan an estimated \$235 billion USD, largely to rebuild the infrastructure erased by the disaster. This reconstruction effort lasted five years. The World Bank states that the earthquake led to a 0.7 percent contraction of Japan's GDP, with the manufacturing sector affected most. Some industries abroad needed to halt production as the disruption to supply chains went global.⁹ In an integrated and central economy like the United States, a localized disaster is sure to have global ramifications.

In 2010 the Eyjafjallajökull volcano in Iceland erupted with a power of 4 out of 10 on the Volcanic Explosivity Index (VEI).¹⁰ Although the eruption was minuscule relative to a potential Yellowstone explosion, the damage it caused had quite an effect on the economy. Water and magma mixed to create an ash and gas plume around 10 km high. European airports had to close for around six days, due the threat of the thick ash damaging airplanes. Hundreds of flights were disrupted. This eruption cost airlines around \$200 million a day. It cost the European travel industry around \$5-10 billion, losses for which they were not insured. The disaster also affected time-sensitive and high value goods such as pharmaceuticals and living organisms, among all other goods

⁶ Rich, Robert. "The Great Recession." Federal Reserve History. Accessed August 3, 2018. https://www.federalreservehistory.org/essays/great_recession_of_200709.

⁷ Ibid.

⁸ History.com Staff. "Great Recession." A+E Networks. Accessed August 3, 2018. <https://www.history.com/topics/recession>.

⁹ World Bank. 2012. "The Great East Japan Earthquake - Learning from Megadisasters: Knowledge Notes, Executive Summary." Washington, DC. World Bank. <https://openknowledge.worldbank.org/handle/10986/17107> License: CC BY 3.0 IGO.

¹⁰ Cottrell, Elizabeth. "What we Know from the Icelandic Volcano." Smithsonian (April 21, 2010).

transported by plane.¹¹ In these cases, delays can mean a decrease, or altogether elimination, of value.

Also important for consideration is the international response to disasters such as this. Typically countries assist each other through foreign aid, either directly through financial assistance or by providing supplies or specialists which are unavailable in the affected country. The US is the largest provider of total “flows” of aid. This is a measure of the combined amount of ODA, OOF, and private money provided.¹² Despite a large drop in the amount provided in 2014, the US still remains the foremost provider in this area. When the US itself is the disaster-zone, the contributions of other nations filling in gaps will be crucial.

The Issues

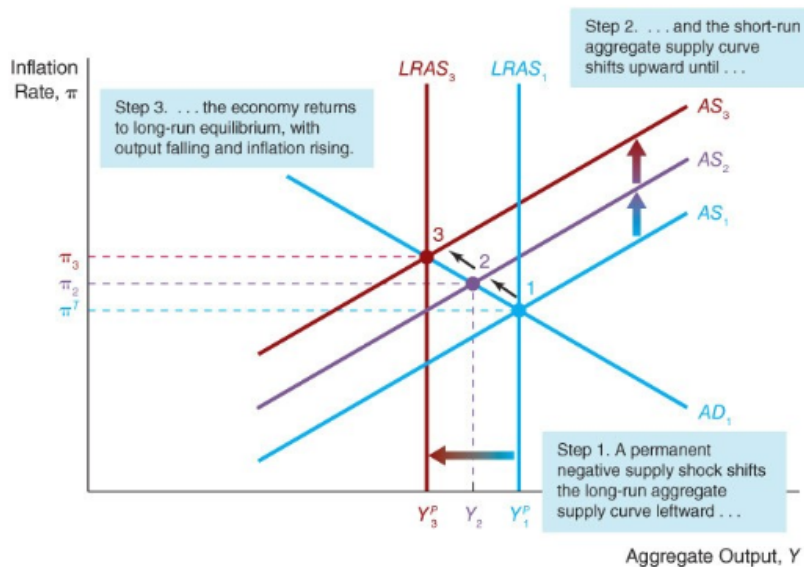
Large scale destruction of property as well as the halting of businesses in affected areas will reduce the ability of producers to provide goods and services. Due to a long-term reduction in the amount of resources available as well as adverse effects on infrastructure, the costs of production in the economy will rise. This leads to increased prices and decreasing levels of output.¹³

The effects of this supply shock and increased costs will vary from one business to another. For those with fixed employment contracts, companies will be forced to lay off workers as it will no longer be affordable for them to maintain their current level of production. Even beyond those who lose their jobs, those who remain employed will face a decrease in their real wage rates, as prices increase and wages stagnate. Those who are not bound to a fixed contract may be able to negotiate a higher wage to keep pace with higher prices.

¹¹Amadeo, Kimberly. "Natural Disasters' Effects on the Economy." The Balance. Accessed August 3, 2018. <https://www.thebalance.com/cost-of-natural-disasters-3306214>.

¹² “Other Official Flows (OOF).”

¹³ Mishkin, Frederic S. The Economics of Money, Banking and Financial Markets. Sixth Canadian edition. Toronto: Pearson, 2016. 589.



An increase in the prices of goods and services creates a rise in the rate of inflation. High inflation is to be avoided since it disincentivizes consumers, firms, and the government from long-term investment decisions. Since the cost of lending is higher, investors will opt to lend at higher interest rates, making it less feasible for small and scaling businesses to retain affordable loans needed to grow their markets. The lack of domestic and foreign investment will slow down the ability of the nation to recover and rebuild affected regions. Concerns of economic growth will be cast aside as the private and public sectors attempt to sift through the rubble of the financial environment.

Inflation may also cause investment spending to decrease as a result of the devaluation of the local currency. In this scenario, an investor will have the returns from his investment lose value over time, as the interest rate set at the time the investment was made no longer reflects the real return the investor wanted. However, it is important to note that a negative or zero rate of inflation is also unpreferable, since it can encourage instability in financial markets and trigger economic contraction.¹⁴

Additionally, higher inflation can depress the stock market as a result of a decrease in business' real profits. This makes a company's future profitability less certain and lowers the value of its stocks, since investors want to either take less of a

¹⁴ Mishkin. The Economics of Money, Banking and Financial Markets. 441.

risk or hold less of said stock.¹⁵ Efforts should be made to ensure financial stability in order to prevent an economic recession or depression.

As detailed previously, the U.S. is the largest supplier of foreign aid in the world, thus the international community may have trouble providing aid.¹⁶ The international community may have to increase their contribution of aid from previous levels in order to manage the crisis. In addition, many countries which rely on foreign aid from the U.S. may lose the aid they were receiving, should it be reallocated to help with the crisis.

According to the World Bank, trade contributes to 56.4 percent of the world's GDP. Furthermore, the two greatest economies in the world are heavily reliant on trade, making up around 26 percent of America's GDP and 37 percent of China's GDP.¹⁷ As detailed in the Infrastructure section of this guide, some aspects of international trade may be disrupted due to ash from the volcano. These include air transport and sea transport. Trade going into the western half of the United States, such as California, will likely be the most affected, due to Yellowstone's position. In addition, trade within the US will be disrupted, as roads are damaged by the eruption or ashfall. This will make it difficult to sustain affected areas with foreign goods that may be needed, such as imported medicine. For countries that trade extensively with the U.S., disruptions to trade may prove disastrous to economies and industrial bases which do not have the capability to produce these goods themselves. A response to this disaster should attempt to minimize the commercial damage that may be caused by a break in trade.

¹⁵ DeFina, Robert H. "Does Inflation Depress the Stock Market?" Business Review - Federal Reserve Bank of Philadelphia (Nov, 1991): 3. <http://search.proquest.com.proxy.lib.uwaterloo.ca/docview/231386109?accountid=14906>.

¹⁶ "ODA 2015 - Detailed Summary." Paris, FR: OECD, 2016.

¹⁷ "Trade (% of GDP)." The World Bank. Accessed August 3, 2018. <https://data.worldbank.org/indicator/NE.TRD.GNFS.ZS>.

GOALS OF A COMMUNIQUE

1. What is the best way to prevent or mitigate the effects of a potential financial crisis, on a nationwide, and worldwide scale?
 2. How will foreign aid for the disaster be distributed, and by whom?
 3. How will international trade continue to flow, given potential disruptions?
 4. How will the world recover from economic damage in the long term
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SECTION 1B: INFRASTRUCTURE

Background

While our means of communication, trade, and relation to the world are becoming increasingly digital, it is important not to underestimate the role that physical capabilities play in society. Strong infrastructure is key to a resilient nation. Consider for a moment a hospital. The space is built up in a way intended specifically to help people heal from illness and injury, and perhaps more importantly, to prevent or delay a loss of life. The hospital could not function as effectively if it were built differently, or filled with different equipment. The same would be true if it were deprived of electricity. If it weren't for the roads and public transportation that deliver patients to the hospital, it would be much less effective. If it lacked running water, the hospital would suffer from unsanitary conditions, a factor crucial to maintain in an environment full of ill patients. All of these are infrastructural capabilities. This is, however, just one example of the importance of infrastructure. Developed infrastructure is crucial to just about everything we do. Another key function of infrastructure is trade. Infrastructure is a necessary support to a flourishing economy for a variety of reasons, including its role connecting supply chains, which allow for the efficient movement of goods and services to different regions and across borders. Each infrastructure sector provides different types of services and goods and they all

have different designs. Infrastructure encompasses goods that are both privately and publicly owned. Some of the most significant examples of public infrastructure are water, roads, electricity and national defense.

Introduction

In 1980, The United States was rocked by one of the deadliest volcanic eruptions on record: the eruption of Mount St. Helens. It is estimated that 200 homes were damaged and 57 people were killed by the immediate aftermath of the eruption. The supply chain of the surrounding area was punished extensively by the eruption. Thirty logging trucks, 22 transport vehicles, and 39 railcars were damaged or destroyed. The eruption of Mount St. Helens caused a total of \$969.8 million in damages.¹⁸ Countless materials and buildings were lost as ice and snow melted, flooding the nearby Toutle River.¹⁹

In 2012, the United States recorded one of its most dangerous natural disasters of all time, Hurricane Sandy. It has been estimated that 650,000 homes were destroyed and there were 233 fatalities in total. Hurricane Sandy caused in total \$71.5 billion in damages²⁰ and drew attention to problems with water infrastructure. Overwhelmed wastewater systems, washed-out roads, shorted electrical circuitry and flooded train stations not only highlighted the economy's reliance on these networks, but revealed the poor condition of the existing infrastructure.²¹ To make sure that the US will be ready if another event like Hurricane Sandy took place, there were damage mitigation strategies put in place. The introduction of sea-gates was intended to protect low-lying areas from a surge of water by creating a barrier between them and rivers. Government organizations also put emphasis on improving the resilience of buildings' roofs, as they are the first line of defense against the elements. Choosing structurally-sound designs and materials allows buildings a higher chance of withstanding natural

¹⁸"Cost of Volcanic Eruptions." Volcano World. Accessed August 3, 2018. <http://volcano.oregonstate.edu/cost-volcanic-eruptions>.

¹⁹ Alan Taylor. "The Eruption of Mount St. Helens in 1980." The Atlantic. May 18, 2015.

²⁰ Amadeo, Kimberly. "How Bad Was Hurricane Sandy?" The Balance. Accessed July 27, 2018. <https://www.thebalance.com/hurricane-sandy-damage-facts-3305501>.

²¹ Puentes, Robert. "Why Infrastructure Matters: Rotten Roads, Bum Economy." Brookings. July 28, 2016. Accessed July 27, 2018. <https://www.brookings.edu/opinions/why-infrastructure-matters-rotten-roads-bum-economy/>.

disasters.²² They also undertook the project of waterproofing utility systems, allowing them to still function in the event of another hurricane or water-related natural disaster. Government actions such as these are often taken reactively, after natural disaster strikes, rather than proactively. As a result, many areas are predisposed to a great deal of risk posed by the elements.

The Issues

There are many issues that would affect the infrastructure of many nations if the Yellowstone volcano erupted. Houses and buildings would be destroyed and people would become homeless, causing panic. One common path to destruction is the combination of moisture and ash collecting on roofs and bridges, becoming extremely heavy and eventually collapsing.²³ It is estimated that since 2008, natural disasters have displaced an average of 26.4 million people per year from their homes. Infrastructural vulnerability also limits economic growth in many cases. A study found that home prices in areas with very low risk of natural disaster grew about 7% faster than those with very high risk for natural disaster.²⁴

Infrastructural damage can further hurt the economy because of the decreased incentive for investors and tourists to visit the area. As for tourism, landmarks that each nation has will be destroyed and this will decrease the value that each nation has economically as millions of dollars will be lost from the tourism industry,²⁵ but tourists will also have the impression of disaster associated with the area, which can further depress their willingness to visit. A similar phenomenon will compel investors to keep their business in areas that are perceived to have less risk, and less cleanup necessary in the wake of the disaster.

²² "Mitigation Lessons from Hurricane Sandy: How to Protect Your Business from the Next Storm." Disastersafety.org. Accessed July 27, 2018. http://disastersafety.org/wp-content/uploads/01-comms-Sandy-lessons_IBHS1.pdf.

²³ ESchooltoday. "The Effects of Volcanic Eruptions." What Are the Effects of Flooding? Accessed July 27, 2018. <http://eschooltoday.com/volcanoes/effects-of-volcanic-eruptions.html>

²⁴ Hill, Catey. "43% of U.S. Homes Are at High Risk of Natural Disaster." MarketWatch. September 03, 2015. Accessed August 03, 2018.

²⁵ Hughes, Amani. "Hawaii Volcano Update: What Are the 'staggering' Costs of Kilauea Eruption? ." Express.co.uk. June 01, 2018. Accessed July 28, 2018. <https://www.express.co.uk/news/world/968056/Hawaii-volcano-update-cost-Kilauea-eruption>

In the event of an emergency, transport system failures across a country and roads destroyed by the eruption would result in difficulties evacuating people. Thick coverings of ash have, in other cases, made roads impassable. Ashes are also harmful to vehicles' internal mechanisms, which can slow down aid efforts. Ash has the further consequences of shutting down all flights within range of the fallout. The ash in the atmosphere has the effect of decreasing visibility, getting caught in engines, and effectively making it too dangerous to fly.²⁶ If Yellowstone were to erupt, it would mean planes from Los Angeles to New York would be grounded. The disruption of the transportation system in such a major economy has a great impact on the global supply chain. For instance, when the 2011 Tohoku earthquake hit Japan, it had a significant impact on the global supply chain because national automobile production fell by 50% in the country that produces the most automobiles in the world. The 2010 eruption of the Eyjafjallajökull volcano in Iceland caused the shutdown of most European and transatlantic transport systems for a week, which caused millions of passengers to be stranded in the airport.²⁷

Should disaster strike, it could affect electrical grids and water systems, which will be crippling, for its interruption of public services such as hospitals, schools and industries. Patients in critical condition will require urgent attention, which may be unavailable due to a lack of electricity and water. On top of this, it is likely that hospitals would have to find ways to deal with an influx of patients injured by the disaster. Common public services, such as public schools, may also have to be shut down due to power constraints or safety concerns. Finally, the industries that call the American west home will take a big hit due to the damage to infrastructure done by a volcanic eruption. Not only will production be slowed; some of the natural resources that America relies on, such as lumber, will be in scarce supply if an eruption wipes out swaths of forest.

Even within private homes, a lack of electricity and water would take its toll. Food in refrigerators and freezers will go bad as little as four hours after the power

²⁶"Impact of Natural Disaster on Infrastructure." UKEssays. Accessed July 27, 2018. <https://www.ukessays.com/essays/environmental-studies/impact-natural-disaster-infrastructure-3242.php>

²⁷ "Transportation and Disasters." The Geography of Transport Systems. June 09, 2018. Accessed August 03, 2018. https://transportgeography.org/?page_id=6295.

goes out, which may cause a food shortage.²⁸ This could be a precursor to the violence and looting that often occurs in disaster zones, as people rush to equip themselves with enough food to last their families through the crisis.

Amidst the chaos, an eruption would most likely bring phone lines are down²⁹, which means that families will have difficulty contacting each other. The fear that accompanies separation from family can often lead to post-traumatic stress disorder, a long-term factor that policy-makers should be mindful of while crafting the relief effort. Lastly, the sewage-disposal system will be flooded with water from melting snow and ice which will therefore contaminate other water collections intended for human use. This poses a threat to sanitation and human health.³⁰

There are other realities unique to the location of Yellowstone that must be faced. Yellowstone is located in a country with a high density of nuclear reactors, which if affected by the eruption, could cause further damage by exploding, or otherwise leaking. The most worrisome reactors are the Columbia Generating Station located in Washington, Cooper Nuclear Station located in Iowa, and the Wolf Creek Generating Station located in Kansas.³¹ These nuclear reactors are in close proximity to the Yellowstone volcano, so they have the highest chance of being affected by the eruption. If these reactors are damaged, they may release radioactive particles into the atmosphere and affect the US and nearby countries. Radioactive fallout may also contaminate water sources. The Fukushima nuclear disaster that happened in Japan in 2011 was due to an earthquake and tsunami destroying nuclear reactors and thus releasing radioactive materials into the environment. Marine life in bodies of water close to the nuclear power plant suffered from “mutations, stunted growth, and

²⁸ "Natural Disasters and Severe Weather." Centers for Disease Control and Prevention. October 17, 2017. Accessed August 03, 2018. <https://www.cdc.gov/disasters/poweroutage/needtoknow.html>.

²⁹ Moore, Mason. "How Will a Yellowstone Super Volcano Eruption Affect Technology?" Quora. April 1, 2017. Accessed July 27, 2018. <https://www.quora.com/How-will-a-Yellowstone-super-volcano-eruption-affect-technology>

³⁰ "Volcanic Ash Impacts & Mitigation - Water Supply." USGS: Volcano Hazards Program CVO Mount Hood. Accessed August 03, 2018. https://volcanoes.usgs.gov/volcanic_ash/water_supply.html.

³¹ "Operating Nuclear Power Reactors (by Location or Name)." United States Nuclear Regulatory Commission - Protecting People and the Environment. Accessed August 18, 2018. <https://www.nrc.gov/info-finder/reactors/>.

reproductive defects if they received a sufficiently high dose”.³² Consumption of fish went down due to fears of poisoning. The possible effects on nuclear reactors must be considered in preparation for a Yellowstone eruption.

GOALS OF A COMMUNIQUE

1. Are there any actions that can be taken prior to the eruption that will mitigate its effects on infrastructure?
 2. What infrastructure should be prioritized in the midst of the rescue and recovery effort?
 3. How can the international community support the United States in their recovery from the disaster? Are they morally or legally obligated to do so?
 4. What can be done to ensure that future events do less damage to the infrastructure of the surrounding regions?
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³² Sarkisan, Dylan. "Effect of Fukushima Nuclear Disaster on Japanese Ecosystems." Fossil Fuel vs. Nuclear Energy. February 20, 2017. Accessed August 03, 2018. <http://large.stanford.edu/courses/2017/ph241/sarkisian1/>.

TOPIC 2

CIVILIZATION

SECTION 2A:
ECONOMY

SECTION 2B:
INFRASTRUCTURE

SECTION 2A: TECHNOLOGY

Background

In the event that a disaster on the scale of a Yellowstone eruption should occur, life on planet earth would be drastically altered. The only way for humanity to continue to live in the surrounding areas would be to develop technology to overcome the fallout of the eruption, and ensure human needs are met. In the immediate aftermath of an eruption, society will have three major environmental challenges to address: food and water security, climate change, and the pollution emitted from the volcano. The massive casualties that will occur and the vital infrastructure that will be destroyed only complicate the matter. Communities and governments will need to get creative in order to find a solution to these problems, as the modern, Western world has never experienced a natural disaster of this level.

Introduction

Due to the extreme nature of the Yellowstone Supervolcano, and its position amidst one of the most developed societies history has known, it is difficult to find a historical parallel to a potential eruption. This makes it difficult to compose a potential action plan based on prior knowledge. Furthermore, the technology used to manage these crises has evolved significantly since the most recent major eruptions, meaning new solutions can be used to mitigate the effects of the volcanic event. While their magnitude pales in comparison to Yellowstone, delegates may rely on responses to recent volcanic eruptions such as Mt. St. Helens in 1980 and the Icelandic Volcano eruptions in 2010 as a template for actions.

The aforementioned Mt. St. Helens eruption was disastrous for the environment, among its other dire consequences. Tens of thousands of acres of forests and arable land were covered in soot, killing many forms of flora and fauna and damaging the local ecosystems.³³ However, not all the effects of the eruption were negative, as plants and animals in areas with a thin coating of ash managed to survive

³³ "A Look at the Mt. St. Helens Eruption 35 Years Later." Washington State Military Department. Accessed August 03, 2018. <https://mil.wa.gov/blog/news/post/a-look-at-the-mt-st-helens-eruption-35-years-later>.

and indeed thrive as the ash improved the fertility of the soil in the area, making agricultural production more efficient. With the far greater quantity of ash that would be deposited by a Yellowstone eruption, these positive side-effects would be reserved for areas 100s of kilometers away from the eruption. Overall, \$2-3 billion in economic damage was caused by the eruption and in response the Washington state government established a public education campaign to prepare people for future eruptions.³⁴ Furthermore, early detection technology was developed to bolster the federal government's National Volcanic Early Warning System to monitor volcanic activity at Mt. St. Helens and other volcanoes across the country. Developed by the US Geological Survey, the system aims to monitor America's most vulnerable volcanoes and plans to update monitoring equipment across these areas. The system further seeks to employ automation to ensure 24/7 monitoring and help scientists and local governments with their responses.³⁵

When in 2010 the volcano Eyjafjallajökull erupted, scientists were concerned that the ash could kill livestock who ingest it and potentially contaminate European water systems. Aside from the immediate environmental damage of the eruption, over 100,000 flights across the north Atlantic were cancelled as European airspace was closed for several days due to the significant amount of ash. This not only caused severe disruption to passengers and airline companies, but estimates show that about 0.025-0.05% of Britain's GDP was lost due to the eruption.³⁶ In terms of long term impacts, scientists believe that it will not be severe as the ash dispersed in the months after the eruption and the amount of carbon emitted is considered relatively insignificant in the global context.³⁷ However, as a result of the mass travel disruption caused by the eruption, the private sector has moved to develop infrared sensors on

³⁴"MSH Impact and Aftermath [USGS]." USGS Publications Warehouse. June 25, 1997. Accessed August 03, 2018. <https://pubs.usgs.gov/gip/msh/impact.html>.

³⁵ Program, Volcano Hazards. "USGS: Volcano Hazards Program." USGS: Volcano Hazards Program CVO Mount Hood. Accessed August 03, 2018. <https://volcanoes.usgs.gov/vhp/nnews.html>.

³⁶ "How the 2010 Ash Cloud Caused Chaos: Facts and Figures." The Telegraph. May 24, 2011. Accessed August 03, 2018. <https://www.telegraph.co.uk/finance/newsbysector/transport/8531152/How-the-2010-ash-cloud-caused-chaos-facts-and-figures.html>.

³⁷ Stone, Daniel. "The Environmental Effects of Iceland's Volcano." Newsweek. May 25, 2010. Accessed August 03, 2018. <http://www.newsweek.com/environmental-effects-icelands-volcano-70371>.

planes to detect ash levels ahead of the plane, helping pilots navigate these dangerous events. In addition, governments are working to improve their satellite monitoring systems so as to improve the quality of the information collected. In fact, scientists estimate that had these measures been put in place in 2010, nearly double the number of flights could have continued rather than been grounded as a result of the eruption.³⁸ It is important to note that a Yellowstone eruption would spew significantly more ashfall than the eruption of Eyjafjallajökull.

The Issues

As stated previously delegates will need to address three critical issues when the Yellowstone volcano erupts, managing resources shortages, climate change and organizing the millions of people whose homes have been completely destroyed.

When Yellowstone erupts, millions of tonnes of ash will cover much of the continental United States, particularly across the Midwest destroying the multitude of settlements and farms of the region. Not only does this mean massive casualties, but also destruction of crops, livestock, and water supplies on an unprecedented scale. Complicating the issue, the ash combined with volcanic winter could make it impossible to grow food in the near future and essentially make the entire US Midwest uninhabitable. However, one possible technology that could be adapted is hydroponics. The concept is essentially growing crops without soil and can be adapted to incorporate fish and other sea creatures to provide food. This technology has the added benefit of being able to grow in artificial environments such as greenhouses, and can be developed in vertical farms requiring less space than a conventional farm.³⁹ On the other hand, hydroponic farming requires large capital investments and human oversight to ensure that plants do not die. However delegates will need to organize the logistics of such technology, find financing, and distribute the food once it is grown.⁴⁰ In regards to water security, desalination is a technology delegates could adapt to

³⁸ Oskin, Becky. "New Tech Helps Pilots Navigate Dangerous Volcanic Ash Plumes." LiveScience. October 13, 2014. Accessed August 21, 2018. <https://www.livescience.com/48260-monitoring-volcanic-ash-aircraft.html>.

³⁹ Baraniuk, Chris. "Future - How Vertical Farming Reinvents Agriculture." BBC News. April 06, 2017. Accessed August 03, 2018. <http://www.bbc.com/future/story/20170405-how-vertical-farming-reinvents-agriculture>.

⁴⁰ "Hydroponics: Advantages and Disadvantages." Dyna-Gro. April 11, 2018. Accessed August 03, 2018. <https://dyna-gro.com/hydroponics-advantages-and-disadvantages/>.

provide drinking water to the millions of now stranded people. Desalination is the process of removing minerals from saltwater to turn it into potable water for human consumption and currently produces less than one percent of daily freshwater consumption. Major users of this technology include Israel, Saudi Arabia, and the states of California and Florida in the United States.⁴¹

With the millions of tonnes of volcanic ash that Yellowstone is projected to spew, delegates need to confront the challenge of climate change and pollution that will result from the eruption. Aside from the extremely polluted air, volcanic winter caused by the massive amount of ash is another concern that could be potentially deadly for the millions living in the affected area. In terms of technology to mitigate this issue, cloud seeding is one options delegates could consider. Cloud seeding is essentially creating artificial rain by injecting chemicals into clouds. These chemicals increase the rate at which ice crystals are formed, and these crystal become rain faster. This could potentially solve water shortages and clear up pollution. The downside to this solution is that it has the side effect of preventing rain from falling elsewhere, which could lead to drought. Additionally, the technology is experimental, and it is not clear how effectively it would work to create artificial rain.⁴² Delegates must weigh these factors as they discuss the use of technology in the wake of a Yellowstone eruption.

Finally, delegates will need to find a way to support the millions of people stranded by the Yellowstone eruption and find ways to reach them. Crucial infrastructure will be destroyed and cities and towns isolated yet resources and emergency services still need to be provided. If possible the Internet of Things could be a way for governments to coordinate their responses and remotely help people stuck in their own homes. Drones could also be used as to help deliver aid and help relevant authorities keep track of what is occurring on the ground level.

⁴¹ Perlman, Howard, and USGS. "Saline Water: Desalination." Livestock Water Use, the USGS Water Science School. Accessed August 03, 2018. <https://water.usgs.gov/edu/drinkseawater.html>.

⁴² Guilford, Gwynn. "China Creates 55 Billion Tons of Artificial Rain a Year-and It Plans to Quintuple That." Quartz. October 22, 2013. Accessed August 03, 2018. <https://qz.com/138141/china-creates-55-billion-tons-of-artificial-rain-a-year-and-it-plans-to-quintuple-that/>.

GOALS OF A COMMUNIQUE

1. What existing technologies can be harnessed most effectively to mitigate the damages caused by Yellowstone?
 2. How will the cost of developing these technologies and coordinating relief efforts be covered and who will determine how any monies provided are to be spent?
 3. What technologies or areas of study should be provided with research and development funds to most effectively bring relief to the victims of Yellowstone?
 4. Should technology and research be provided primarily from government resources, or should there be a degree of cooperation with the private sector? In what capacity?
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SECTION 2B: SOCIETY

Background

A massive volcanic eruption will affect the fabric of society in many ways. Most obviously, there will be immense demographic changes. With vast numbers of residents in the area of the eruption being required to evacuate their homes, the likely result will be massive influxes of displaced persons throughout the United States and neighbouring countries. Areas once teeming with life may transition to barren ghost towns, unsafe for people to inhabit. Other changes that may not be as obvious are the potential cultural shifts that may follow a supereruption. Such potential shifts may range from minimal to extreme in terms of their effect on society and the number of people affected. For example: stigmatisation leading to the division or segregation of a population; the creation of new cultural norms, or the creation of quasi-militia groups that may in turn kickstart the creation of extreme political parties. While the aforementioned are just a handful of the many ways society may be affected, it can be seen that the effects of a Yellowstone volcanic eruption on the population are potentially disastrous, and must be handled with the utmost care.

Introduction

Considering the effects of past volcanic eruptions is useful in predicting the results of an eruption from the Yellowstone Caldera. One major eruption was that of Mt. Tambora in Indonesia. The eruption in 1815 killed 117 000 people: some directly from the eruption, but some as a result of a rising tidal wave, famine and disease, and through migration and flight.⁴³ Moreover, the eruption destroyed two princedoms: the Princedom of Pekat and the Princedom of Tambora. Upon such a destruction, the Tambora language became extinct. Many survivors sought refuge elsewhere, and important chief towns and ports never recovered from the disaster.⁴⁴

Another historical analog was the 1902 eruption of Mt. Pelee in the West Indies. The volcano was located close to the town of St. Pierre, and its blast immediately killed nearly all 30 000 of St. Pierre's residents.⁴⁵ The majority of immediate deaths were caused by suffocation and burns, as there were "estimates suggesting the gas cloud was between 350 and 500 degrees Celsius". The multiple eruptions of Mt. Pelee have been considered some of the deadliest disasters in recorded history. Further terror in the surrounding area took place when swarms of insects and reptiles arrived in human settlements, disturbed by the volcanic activity.⁴⁶ Two meter long pit vipers killed hundreds of animals and dozens of people. Thus, the eruption of Mt. Pelee had major societal effects on the population of St. Pierre and the surrounding area, creating major demographic changes within the area.

The Issues

A major issue that will result from a super eruption is violence and conflict. Studies have suggested that self-directed and interpersonal violence may increase following natural disasters. An increase in violence may result due to factors that lead to distress, which then develop into violence. Such factors include scarcity of

⁴³ Bernice De Jong Boers, "Mount Tambora in 1815: A Volcanic Eruption in Indonesia and Its Aftermath," *Indonesia*, no. 60 (October 1995): , doi:10.2307/3351140, 39-44.

⁴⁴ *Ibid*, 43.

⁴⁵ Julia Rosen, 2015, "Benchmarks: May 8, 1902: The Deadly Eruption of Mount Pelée," *Earth Magazine*, American Geosciences Institute, May 8. <https://www.earthmagazine.org/article/benchmarks-may-8-1902-deadly-eruption-mount-pelee>.

⁴⁶ *Ibid*.

necessities, failure of law enforcement, and feelings of powerlessness.⁴⁷ Additionally, it has also been found that exposure to natural disasters increases violence against women and girls, child PTSD, and child abuse.⁴⁸

The long-term effects of a disaster may also affect levels of violence in an area. According to the World Health Organization, increased levels of community violence are a long-term result of disasters. It is also believed that the distribution of emergency aid may play a role in violence within a stricken community or area.⁴⁹

Natural disasters often increase the levels of theft in an area. Thieves, often referred to as looters, are all too common in post-disaster scenarios. During Hurricane Katrina, quasi-militia groups formed due to fear of looters; the said groups then performed racially motivated violence. However, many of the items stolen were necessities that couldn't be afforded by some residents, such as food and diapers.⁵⁰ Furthermore, Hurricane Katrina also resulted in police killings, white vigilante violence, and official cover ups. One of the most notorious events was the Danziger Bridge shooting in eastern New Orleans: a group of police officers fired on unarmed civilians, wounding a family of five and killing two.⁵¹ These kinds of events are indicative of the importance of ensuring human rights are met in the aftermath of a potential disaster.

The United Nations has guiding principles on internal displacement.⁵² It should be ensured that these are being followed, although it may be difficult to maintain a strict set of policies amidst such a hectic atmosphere. While park officials and tourists are already being evacuated from the park, there is a chance that these numbers will

⁴⁷ Mohsen Rezaeian, 2013, "The Association between Natural Disasters and Violence: A Systematic Review of the Literature and a Call for More Epidemiological Studies," *Journal of Research in Medical Sciences: The Official Journal of Isfahan University of Medical Sciences* 18 (12): 1103-7.

⁴⁸ Ibid.

⁴⁹ "Violence and Disasters," 2005, *Violence and Disasters*, Geneva: World Health Organization: Department of Injuries and Violence Prevention.

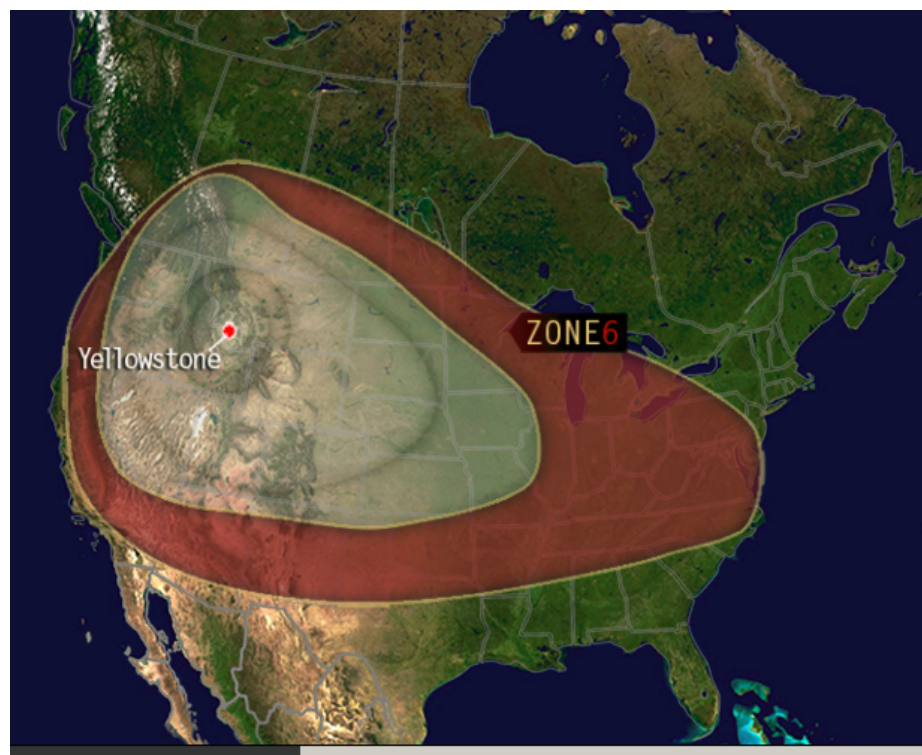
⁵⁰ Mark Guarino, 2015, "Misleading Reports of Lawlessness after Katrina Worsened Crisis, Officials Say," *The Guardian*, *Guardian News*, August 16, <https://www.theguardian.com/us-news/2015/aug/16/hurricane-katrina-new-orleans-looting-violence-misleading-reports>.

⁵¹ Trymaine Lee, 2010, "Rumor to Fact in Tales of Post-Katrina Violence," *The New York Times*, *The New York Times Company*, August 26, <https://www.nytimes.com/2010/08/27/us/27racial.html>.

⁵² "Guiding Principles on Internal Displacement," n.d., *Guiding Principles on Internal Displacement*, The UN Refugee Agency.

be dwarfed by the hundreds of thousands of residents evacuated and displaced from their homes if the volcanic activity escalates. The eruption of La Soufrière volcano in Guadeloupe in 1976-1977 left 76 000 people displaced for three to six months.⁵³ During this time, twenty-four percent of the displaced population lived on host communes, in schools or in billet homes.⁵⁴

Upon the eruption of the Yellowstone volcano, there will be six “zones” affected by its eruption. All those within the first five zones (over 800 km away from the eruption) will be displaced (see fig. 1). Ultimately, it is estimated that over 15 million people will be displaced.⁵⁵



⁵³ Marie Chenet, Delphine Grancher, and Marie Redon, 2014, “Main Issues of an Evacuation in Case of Volcanic Crisis: Social Stakes in Guadeloupe (Lesser Antilles Arc),” *Natural Hazards* 73 (3), 2127.

⁵⁴ *Ibid*, 2129.

⁵⁵ “Supervolcano: Yellowstone's Fury,” n.d., CBC Doc Zone, Canadian Broadcasting Corporation, <http://www.cbc.ca/doczone/features/the-zones>.

Furthermore, because those who cross borders are not considered refugees under the 1951 Refugee convention, there may be a gap in protection for those who choose to flee from the disaster to find refuge in a different country.⁵⁶ Those who flee, who are evacuated, or who are forcibly uprooted due to natural disaster are considered internally displaced persons, and thus the Guiding Principles on internally displaced persons apply to them. However, some international experts and government members do not agree, and think that internally displaced persons should only be those uprooted due to conflict.⁵⁷ A prime example of this is the United States during Hurricane Katrina. While disaster struck, the government used every term other than Internally Displaced Person (IDP), because “IDP in their view were generally people displaced by conflict ‘overseas’”; thus, the government did not feel obliged to apply the guiding principles on IDPs.⁵⁸ Furthermore, the US Agency for International Development stated in 2004 that “the United States does not accept the UN Guiding Principles as an expression of governing international law”.⁵⁹ Officials were uninterested in a rights-based approach to disaster victims, and thus citizens and organizations should be wary of the government’s approach, if another disaster were to occur.

A final issue potentially at play is stigmatisation. Upon the eruption of La Soufrière volcano in Guadeloupe in Basse Terre, people from Grande Terre nicknamed those affected in Basse Terre ‘magmas’, ‘sulphur’, ‘mixed veg’, and ‘turkey wings’.⁶⁰ While such names may seem harmless, there is the potential for stigmatisation that is more fierce and that affects people strongly.

⁵⁶ Roberta Cohen and Megan Bradley, 2010, “Disasters and Displacement: Gaps in Protection.” *Journal of International Humanitarian Legal Studies* 1 (1): 95-142, doi:<https://doi.org/10.1163/187815210X12766020139884>.

⁵⁷ Ibid.

⁵⁸ Ibid.

⁵⁹ Ibid.

⁶⁰ Marie Chenet, Delphine Grancher, and Marie Redon, 2014, “Main Issues of an Evacuation in Case of Volcanic Crisis: Social Stakes in Guadeloupe (Lesser Antilles Arc),” *Natural Hazards* 73 (3).

GOALS OF A COMMUNIQUE

1. How will displaced persons be dealt with? How will they be accommodated, and on whose dime?
 2. How will it be ensured that Internally Displaced Persons are treated in the correct manner?
 3. How will legal control over private citizens and the police force be maintained?
 4. To what extent should the United States and the international community be involved in the aftermath of the disaster?
-

MAJOR PLAYERS

UNITED STATES OF AMERICA

It goes without saying that the US federal government will play a critical role in dealing with the aftermath of the Yellowstone eruption. As the country in which the disaster will occur, it will have the most resting on an efficient response. The federal government has control over a multi-trillion dollar budget, the largest military budget in the world, and numerous organizations such as FEMA to assist with the rebuilding of affected areas. Aside from being the location of the crisis, the nation houses the two largest stock markets in the world; the New York Stock Exchange and NASDAQ.⁶¹ It is the largest economy in the world, and the largest supplier of foreign aid.⁶² The American economy is the heart of the world's economy, and allowing it to fail will have consequences worldwide.

CANADA

America's closest ally and Northern neighbor will have a big role to play in the recovery effort from a potential Yellowstone eruption. The two nations share the longest land border in the world, and Canada's South-Western regions will likely be within range of ash fallout from the blast. The majority of the damage is likely going to be economic, as the country's economy is deeply entwined with America's. Canada is the United States' second largest goods trade partner. Additionally, the U.S. has a \$71.1 billion trade deficit with Canada, meaning they are a net importer of U.S. goods.⁶³ Canada's economy further relies on the American economy by way of NAFTA, their free trade agreement with each other and Mexico. Thus, interruptions to trade caused by the volcano could severely impact the Canadian economy. Canada will also play a major role as a potential place of refuge for those fleeing the eruption.

⁶¹ Wee, Y. R. "Biggest Stock Exchanges in the World." World Atlas. Accessed August 3, 2018. <https://www.worldatlas.com/articles/biggest-stock-exchanges-in-the-world.html>.

⁶² Smith, Rob. "The World's Biggest Economies in 2018." World Economic Forum. Accessed August 3, 2018. <https://www.weforum.org/agenda/2018/04/the-worlds-biggest-economies-in-2018>.

⁶³ "Canada." Office of the United States Trade Representative. Accessed August 3, 2018. <https://ustr.gov/countries-regions/americas/canada>.

MEXICO

Mexico also shares a large border with the United States, and may be affected by the blast. However, they are more likely to suffer economically from the crisis as they are deeply linked with trade to the U.S. In 2017, the United States had a \$64.1 billion trade deficit with Mexico in goods and services, and it is the United States' third largest goods trading partner.⁶⁴ Mexico is also a member of NAFTA, along with Canada and the U.S. Given these realities, Mexico will be a key player in an event as catastrophic as a Yellowstone eruption. Along the American-Mexican border, authorities may have to deal with an influx of Americans fleeing into Mexico.

CHINA

China has the second largest economy in the world, which puts them in a prime position to help the US, Mexico and Canada with their rebuilding effort after the volcanic eruption. China has also proven increasingly willing to participate in infrastructure building worldwide. They may be called upon to aid in the rebuilding effort. China also depends heavily on trade with the United States. According to the Office of the United States Trade Representative; China was the US' largest supplier of goods in 2016, and the US' third largest export market. In the same year, US goods/ services trade was an estimated \$648.5 billion.⁶⁵ Trade disruptions due to the eruption could deeply impact the Chinese economy and the availability of goods in the United States. In order to preserve their own economy, it may be necessary to help the United States rebuild quickly.

⁶⁴ "Mexico." Office of the United States Trade Representative. Accessed August 3, 2018. <https://ustr.gov/COUNTRIES-REGIONS/AMERICAS/MEXICO>.

⁶⁵"The People's Republic of China." Office of the United States Trade Representative. Accessed August 3, 2018. <https://ustr.gov/countries-regions/china-mongolia-taiwan/peoples-republic-china>.

UNITED KINGDOM

A key player in the world financial system, the United Kingdom hosts the London Stock Exchange Group, the third largest exchange in the world.⁶⁶ Should American markets fail, it may be required to step in to a leadership role on the global stage. The UK is the fifth largest economy in the world, valued at 2.94 trillion.⁶⁷ Although it trades quite extensively with the United States, it will be expected to step up as an alternative economic leader in times of crisis.

WYOMING

As the state in which Yellowstone is located, Wyoming must have a seat at the table. Representatives of the state will be in close contact with those affected directly by the blast, and will therefore be in touch with the priorities of residents. They will be able to determine what issues need to be resolved first and the best methods of coordinating responses in their communities.

NEW YORK

New York State houses the two largest stock markets in the U.S. and the world.⁶⁸ The city of New York alone has two of the busiest airports in the country, LaGuardia and John F. Kennedy, which together manage nearly 45 million flights per year. Even in their position across the country from Yellowstone, New York's airports could be halted by volcanic ash in the air and on their equipment.

UTAH

Counterintuitively, most of the damage to the American economy would not be to the states in the immediate proximity of the eruption. While Wyoming would have to deal with the most traumatic aftermath, and surrounding states like Idaho and Montana will get more ash than further states, their economies are relatively small.

⁶⁶ Wee. "Biggest Stock Exchanges in the World."

⁶⁷ Smith. "The World's Biggest Economies in 2018."

⁶⁸ Wee. "Biggest Stock Exchanges in the World."

While each of these states has a GDP in the \$40-70 billion range, a slightly farther state like Utah has a much larger economy at more than \$165 billion in 2017.⁶⁹

COLORADO

In a similar situation to Utah, Colorado's economy is much larger than states that are nearer to the volcano, at \$342 billion in 2017.⁷⁰ Despite not being at the center of the destruction, Colorado will still be in a position to get a large amount of ashfall, resulting in trouble for businesses and other services. The state can also expect to play host to many internally displaced peoples, as a state outside of the immediate blast-zone, but still a fairly close place of refuge.

⁶⁹ "Gross Domestic Product (GDP) by State (Millions of Current Dollars)." Bureau of Economic Analysis. Accessed August 21, 2018. <https://apps.bea.gov/iTable/iTable.cfm?0=1200&isuri=1&reqid=70&step=10&1=1&2=200&3=sic&4=1&5=xx&6=-1&7=-1&8=-1&9=70&10=levels#reqid=70&step=10&isuri=1&7003=200&7035=-1&7004=naics&7005=1&7006=xx&7036=-1&7001=1200&7002=1&7090=70&7007=-1&7093=levels>.

⁷⁰ "Gross Domestic Product (GDP) by State (Millions of Current Dollars)."

GLOSSARY

Depression: A period of economic activity that constitutes a severe recession, particularly in which the decline in GDP exceeds 10 percent.⁷¹

Gross Domestic Product (GDP): A representation of the total the monetary value of all goods and services produced within a nation’s geographical borders during a specified period.⁷²

Internally Displaced Person: Those forced to flee their homes or places of habitual residence due to armed conflict, internal strife, violations of human rights, or natural or man-made disasters, and who have not crossed an internationally recognized state border.

Internet of Things: A network of devices that connect and interact with each other via the internet.⁷³

Lahar: A landslide of wet volcanic debris on the side of a volcano.

Official Development Assistance (ODA): Funds flowing from official agencies, including governments, to developing countries and multilateral institutions, with the goal of promoting economic development and the welfare abroad. They must include a grant element.

Other Official Flows (OOF): Official sector transactions that do not meet official development assistance criteria.⁷⁴

⁷¹ <http://www.imf.org/external/pubs/ft/fandd/2009/03/basics.htm>

⁷² "Gross Domestic Product." Merriam-Webster. Accessed August 21, 2018. <https://www.merriam-webster.com/dictionary/gross%20domestic%20product>.

⁷³ Burgess, Matt. "What Is the Internet of Things? WIRED Explains." WIRED. February 16, 2018. Accessed August 21, 2018. <https://www.wired.co.uk/article/internet-of-things-what-is-explained-iot>.

⁷⁴ "Other Official Flows (OOF)." OECD. Accessed August 3, 2018. <https://data.oecd.org/df/other-official-flows-oof.htm>.

Power Grid: A network of electrical transmission lines connecting a multiplicity of generating stations to loads over a wide area⁷⁵

Primary Sector: The sector of the economy that deals with transforming raw materials into usable materials.

Private Sector: The part of a country's economy which consists of industries and commercial companies that are not owned or controlled by the government.

Public Sector: The part of a country's economy which is controlled or supported financially by the government.

Refugee: A person outside of the country of their nationality due to fear of being persecuted for reasons of race, religion, nationality, membership of a particular social group or political opinion.

Recession: "A recession is a significant decline in economic activity spread across the economy, lasting more than a few months, normally visible in real GDP, real income, employment, industrial production, and wholesale-retail sales. A recession begins just after the economy reaches a peak of activity and ends as the economy reaches its trough."⁷⁶

Research and Development (R&D): The work a business or organization conducts to advance the innovation, introduction and improvement of products and procedures.⁷⁷

Secondary Sector: The sector of the economy that is tasked with using the raw materials produced by the primary sector to manufacture consumer goods.

⁷⁵ "Power Grid." Merriam-Webster. Accessed August 03, 2018. [https://www.merriam-webster.com/dictionary/power grid](https://www.merriam-webster.com/dictionary/power%20grid).

⁷⁶ http://www.nber.org/cycles/jan08bcdc_memo.html

⁷⁷ "Research and Development - R&D." Investopedia. April 25, 2018. Accessed August 03, 2018. <https://www.investopedia.com/terms/r/randd.asp>.

Supply Chains: A supply chain is a network between a company and its consumers that works to distribute the company's goods in ways that make consumption easier for the company's market.

Volcanic Winter: A cooling of the Earth's surface resulting from the deposit of massive amounts of volcanic ash and sulfur aerosols in the stratosphere.⁷⁸

Wastewater Systems: Any of the mechanical or chemical processes used to modify the quality of wastewater in order to make it more compatible or acceptable to humans.

Volcanic Explosivity Index (VEI): A measure of the relative explosiveness of volcanic eruption.⁷⁹

⁷⁸ Rafferty, John P. "Volcanic Winter." Encyclopædia Britannica. August 30, 2011. Accessed August 03, 2018. <https://www.britannica.com/science/volcanic-winter>.

⁷⁹ Newhall, C. and S. "The Volcanic Explosivity Index (VEI) an Estimate of Explosive Magnitude for Historical Volcanism." *Journal of Geophysical Research: Oceans* 87, (1982): 1231-1238.

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