Annotated Literature Review of Economic Analysis of Water Impacts from Climate Change

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For Dr. Patrick Welle and the LCCMR

Introduction: The following reference list is divided into two sections. The first covers literature related to economic modeling of climate change. The second section covers information about effects to water systems. The sources in each section are organized alphabetically. The annotations have a half-inch indent. The sources are not indented.

Economic Modeling Resources

Hope, C. (2003). "The Marginal Impacts of CO2, CH4 and SF6 Emissions." Judge Institute of Management Research Paper No.2003/10, Cambridge, UK, University of Cambridge, Judge Institute of Management.

This source provides the primary economic model for the popular Stern Review published recently by the English treasury. Hope illustrates the PAGE2002 model, which uses a discount rate of 3% per year discounted back to the year 2000. The time span is over the next two centuries, from 2000 to 2200. First, this source shows how marginal impact is calculated. Next, CO2, CH4 and SF6 are analyzed for their marginal impacts in 2000 US dollars. The marginal impacts are said to justify the mitigation costs if they are below the damages.

The IPCC scenario A2 and B2 are mentioned, but A2 is specifically utilized. These scenarios show different emission levels with different rates of population growth and GDP changes.

The PAGE2002 model is an updated form from the 1995 model that analyzes several variables. First, it adds a third GHG, SF6. It also takes into special account the cooling effect from the properties of sulphate aerosols including backscattering and solar radiation and

inhibiting cloud production. Third, the source examines thresholds and what the impact is when these are breached. Next, regional growth in GDP is measured. Fifth, adaptation levels are taken into account. The source also considers the amount of CO2 that makes it into the atmosphere. Radiative forcing is another scientific variable considered by this source.

The PAGE2002 model lists that there are 6 different scenarios in the IPCC's TAR. As mentioned previously, only one scenario, A2 is utilized. This scenario assumes no intervention or control.

The discount rate criticism of the Stern Review cited in sources such as Nordhaus (2008) does not consistently match up with the data that is present. The Stern Review cites Hope as the main economic model used for its statements for mitigation. The Hope model uses a discount rate of 3%. Perhaps the difference in discount rate estimates is between Nicholas Stern's discount rate and Hope's discount rate.

The marginal damage calculated was based on findings from a 10% reduction of carbon dioxide. This was repeated at 20% to check for errors. It was found that NH4 and SF6 have factors of 21 and 40,000 times the impact of carbon dioxide. The source further lists drawbacks of projects versus the method of creating marginal impacts, which have economic and real world validity.

It was found that little change existed between the marginal impacts from the 1995 model and the 2000 model. For example, the cost per ton of carbon decreased from $21 to $19. This was found by updating the dollar values from 1995 to 2000. Also, the differences between these prices are discussed. For example, updated scientific information has concluded the decreased ability for oceans to remove carbon dioxide when the temperature is high.

Lastly, the source emphasizes that for future studies, more than one scenario should be utilized from the IPCC's TAR. This would improve the validity for marginal damage estimates and provide a more accurate picture of potential results (the proper marginal damage estimates will lead to proper policy related to mitigation).

Mendelsohn, Robert O. (2006). "Is there a case for aggressive, near-term mitigation of greenhouse gasses? A Critique of the Stern Report." Regulation, Winter 2006-2007.

This article critically examines the Stern Report's methodologies on several main points and proves to be an informative tool for understanding the reasoning behind the suggestion toward high level mitigation procedures in the near-term. The source identifies and questions the fact that the Stern Report concludes an initial rapid mitigation at a high cost will be lowered in the future due to increases in technology. The reasoning behind this conclusion and the underlying methodologies are highly scrutinized by this economist.

The report lists several factors explaining why the Stern Report estimates climate change will be more costly. First, the demographic assumptions are reviewed. This includes information on the population growth rate and the per capita income. Second, the discount rate is examined. The low discount rate in the report is scrutinized, because it is based on an ethical responsibility to future generations saying that they are equally important to those alive currently. For example, the rate is extended until 2200, saying this time period is equal, giving a 1.4% discount rate. Third, the report is criticized for assuming no adaptation to the problems incurred from climate change such as building dams. It is suggested that the costs of climate change could be overestimated with no adaptation. Fourth, the paper points out that extreme weather is cited to incur damages even though the IPCC points to uncertainty in this conclusion. Fifth, the non-market damages of climate change in the report are criticized to be too high of a proportion of GDP and quotes the 5% statistic in 2200 to be very high, projecting to be $23 trillion per year. Sixth, the report's inclusion of knock-on damages or cascade costs of climate change such as decreased investments could potentially go in an opposite direction according to the report. For example, Mendelsohn points out if warming turns out to be less severe, mitigation costs could cause knock-on costs similar to those implied to occur from climate change. Seventh, the risk premium used by the Stern Report is criticized as being possibly unnecessary. Eight, the review's use of equal weight to damages to poor people, through the use of equity, is questioned for its logic.

The paper criticizes that if these above assumptions were not followed, there would be a possible overestimation of the costs of each ton of CO2, expressed as a percentage of income. The overestimation is compared to the author's own estimation, which lowers the 5% cost of income in the Stern Review to .1% of GDP. This assumes only small changes in extreme events and markets through 2100.

Furthermore, the paper scrutinizes mitigation strategies for their feasibility. The Stern Report makes assumptions of the assumed static nature of systems such as no increases in land use crops.

Lastly, the marginal damage theory is discussed for its strength. The paper indicates that this method implies that each extra ton of CO2 would essentially cost nothing, since it would not impact the goal of 550 ppm concentration of CO2. The method of marginal logic is questioned along with the basis for the selection of 550 ppm as a concentration level.

Nordhaus, W.D and J.G. Boyer (2000). "Warming the World: the Economics of the Greenhouse Effect." Cambridge, MA: MIT Press.

This source is specifically cited in the Stern Review as a key source for illustrating the economic estimates for global impacts from increased carbon dioxide. The information in this source was specifically examined for its analysis on non-market impacts from rising carbon dioxide. It first illustrates the gap of empirical evidence in this sector. Time use is emphasized as a key impact area in non-market sectors. In addition, the impacts on human health, settlements and ecosystems are also evaluated.

These authors outline three studies of non-market activities. They touch on a study by Nordhaus that covers University of Michigan surveys of non-market time in 1975 and 1981. These analyzed climate sensitive activities involving people's use of time and found that less than 5% were climate sensitive. The other study considered is Robinson and Godbey (1997) that explores outdoor leisure as a major nonmarket sector. They indicate that surveyed Americans in 1985 spent nearly 39 free hours a week, of which 2.2 hours were climate sensitive activities. At least 2% of .77 hours were spent specifically doing outdoor recreation. They conclude that out of 235 million participants, only 2.5 million participate in activities negatively affected by a warming climate such as skiing and hockey. Other activities are said to benefit due to the increased temperatures.

A study by Nordhaus (1998c) is also analyzed. An intensive study of time use for 100 people in different regions of the country (US) was analyzed. It was found that time gained by warm weather activities such as camping would outweigh time lost by cold weather activities such as skiing. There appears to be a lack of similar studies. Technological changes are ignored

since the determinants of time are physiological. Different regional effects were calculated by multiplying time by average wage, which should be equal to share in GDP. Assuming there are 1500 hours per worker and no income elasticity, they conclude that a warmer climate may see negative effects, where cold and temperate climates may see positive effects (however, this source discounts the value of wintertime activities as being equal to summer. Summer and winter activities may both be considered essential in an outdoors person's point of view).

Nordhaus, William (2008). "A Question of Balance: Weighing the Options on Global Warming Policies." New Haven, Yale University Press.

This source explains a detailed model of methods and an estimate of the costs related to global climate change. A focus was paid specifically on the book's critical review of the Stern Review. It outlines that the Stern Review was written as a policy tool that was not peer reviewed, and has a low reproducibility. It explains in detail the problem with the Stern Review's use of a low discount rate (about .1). It gives the argument that indicates intergenerational equity is like carrying a baton in a race. To give future generations an improper discount rate would be to drop the baton in a race. This is the ethical argument spelled out by the Stern Review. However, Nordhaus points out that modern practices in the economy do not practically reflect this line of reasoning. He further illustrates that reducing spending now would increase savings to the benefit of future generations, making them richer. This previous argument points out the logic behind the conventional model (argued against in the Stern Review, which says immediate mitigation is necessary) that indicates a ramp up on policy. A policy ramp would include slow, then fast mitigation when it is cost effective. Nordhaus further relates consumption to discount rates and discusses their significance. In addition, he analyzes consumption elasticity versus the time discount rate.

Nordhaus is critical of the Stern Review and the main study it cites for an economic model (seen in this annotated collection):

> "It is virtually impossible for those outside the modeling group to understand the detailed results of the Stern Review. It would involve studying the economics and geophysics in several chapters, taking apart a complex analysis (the PAGE

> [Policy Analysis of the Greenhouse Effect] model), and examining the derivation and implications of each of the economic and scientific judgments. Understanding the analysis is made even more difficult because the detailed calculations behind the Stern Review have not been made available."

Nordhaus further criticizes the Stern Review by comparing it against his personal model, DICE, with three different runs: zero discount, zero discount and different consumption elasticity, and optimal policy from DICE 2007. This impacts savings and returns rates, which are claimed to be unrealistically modeled previously.

He touts a similar analysis by Hope (PAGE), that changing discount to .1 raises a carbon cost from $43 to $364 per ton of carbon. He reports that similar findings were found in the DICE model. Therefore, the discount rate appears to be the major weakness of the Stern Review.

Stern, Nicholas (2006). "Chapter 5: Costs of Climate Change in Developed Countries." *Stern Review on the Economics of Climate Change*. London, UK: Her Majesty's Treasury. Available online < http://www.hm-treasury.gov.uk/sternreview_index.htm>.

This source leads up to the next chapter's description of modeling by laying out variables to be considered. It covers a range of agricultural impacts. The source discusses heating costs and overheating deaths. It touches on extreme weather patterns and past impacts on GDP such as hurricane Katrina. Insurance premiums are covered, and the domino effect into other financial sectors and non-market sectors are discussed. Overall, this source examines different ideas of impacts to social welfare by analyzing individual variables.

Stern, Nicholas (2006). "Chapter 6: Economic modeling of climate change impacts." *Stern Review on the Economics of Climate Change*. London, UK: Her Majesty's Treasury. Available online < http://www.hm-treasury.gov.uk/sternreview_index.htm>.

This document provides a detailed description of a few main aspects regarding the estimates of the global cost of global climate change. First of all, assumptions are made regarding climate change. It is assumed that a business as usual approach will exist in respect to

the discharges of greenhouse gasses such as carbon dioxide. Second, the model lists detailed factors that may be included in an impact assessment model (IAM) and provides examples of different models. Third, the sources of current climate projection information are revealed as predictors of temperature increases. Fourth, a final assessment is made regarding how global GDP affects global consumption, which in turn, impacts social welfare.

The model lists factors that are predictors in previously published IAMs. These IAMs report a spectrum of varying economic impacts from very little significant change to drops in GDP that are quite large in respect to changes in global climate. Three of these models are explained below.

First, the Mendelsohn model uses strictly market values of agriculture, forestry, energy, water and coastal zones to conclude that there would be no significant impact from climate change. Second, the Tol model extends the determinant factors to include market and non-market values. This model curiously shows an initial increase of GDP from the first initial sign of warming and then an overall decrease of GDP from an increased amount of warming. Third, the Nordhaus model also uses market and non-market impacts, but also takes into account "large-scale changes" such as El Nino and changes in monsoon patterns. Changing determinant factors such as market and non-market values and including catastrophic changes drastically changes the IAMs.

The Stern Review model is based on the predictions published in the IPCC *Third Assessment Report*. This report provides the baseline, conservative estimate of a 3.0-5.3 degree Celsius change in temperature by the year 2100. The baseline information is then extended to a high climate scenario (of which sources are cited in Chapter 1 of the Stern Review). This scenario includes the instance of the decreased ability for natural sources to act as carbon sinks and increased feedback loops such as methane releases from the thawing of permafrost. Using a range of conservative and extended methods, a spectrum of effects is created.

Next, a mathematical equation ensues. An estimated baseline GDP growth is run against global climate change factors, which results in percentage losses of GDP. These percentage losses are based off the PAGE2002 IAM published by Hope (2003). 1000 runs of global GDP from 2001 to 2200 are calculated. Each of these runs is then divided into GDP per capita and by a constant population growth rate. Each run is then divided by global consumption per capita (population scenario), which is estimated to be the savings rate of 20%. Consumption is then

transferred into utility, which is further transformed into social welfare. In summary, two main factors impact the variation of the IAMs in respect to global climate change. The first is the utilization of market and non-market forces. Second is the decision to use baseline climate change data or to use extended scenarios such as those including feedback loops.

Tol, Richard S.J. (2001). Estimates of the Damage Costs of Climate Change. *Environmental and Resource Economics* 21: 135-160.

This article cited in the *Stern Review* aims to use economic modeling to monetize the impacts of global climate change worldwide. The author divides the world into separate regions, North America being separate, each with their own qualities and variations in responses to the impacts of climate change. Next, different categories are indicated that may be economically affected by the alteration of climate. First, agriculture is examined for changes in crop yield combined with the influence of trade. Second, forestry is analyzed. It is cited that forestry has a linear relationship with climate change and that forestry will grow at the same rate as agriculture. Third, water resources are examined. The equation developed is used for the purpose of solving the water resources impact alone and cannot be extrapolated, because it relies on a single source for its variables. The variables include the region, income, temperature and time. Fourth, energy consumption is reviewed. The article looks at several variables including the income elasticity for heating and cooling energy, to understand the demand for these sectors in response to factors such as improved energy efficiency. Fifth, sea level rise is examined, but since it does not pertain to a study on Minnesota economics, it will not be analyzed further. Sixth, ecosystems are examined with a willingness to pay approach valuing these systems with a "warm glow" attitude toward their existence. Seventh, vector borne diseases are discussed. These produced no economic impact in North America. Lastly, heat and cold stress were examined with their effects on the health of human beings. The mortality from these stresses, as in all previous estimates, is displayed in terms of losses in GDP.

Tol, Richard S.J. (2005). "The marginal damage costs of carbon dioxide emissions: an assessment of the uncertainties." *Energy Policy* 33: 2064-2074.

This is an incredible source that can serve as a jumping point in many tangents for the subjects relating to the economics of mitigating climate change. The issue of weighing abatement costs versus the damage is laid out as one of the major determinants for the necessity of analysis. The source examines 27 independent studies with 94 estimates and creates a new model based on these assumptions. The reference list is very extensive and thorough.

In its analysis, the study points out major argument points of the literature. First, it covers the weaknesses of incomplete market information and climate variability. Next, it examines adaptation estimates, which depends on mitigation goals such as the business as usual (BAU) approach (which the Stern Review assumes). Third, it takes into account that adaptation may reduce costs of climate change. For example, a malaria vaccine would lower damage costs in the vector-born disease category.

This study analyzes the impacts from a doubling of carbon dioxide in the published literature. Each source is scrutinized for its validity and credibility of methods. For example, it was found that high estimates have a high vulnerability and a low discount rate. This has been argued from an ethical standpoint to be just (and is utilized in the Stern Review). It says that there is a moral obligation to protect future generations as much as those in the present. The counter argument is that in practice, current discount rates do not reflect this line of reasoning. The discount rate accounted for a large portion of variability between sources.

Each of the 27 studies was analyzed for its estimates of the marginal damage costs in terms of the price per ton of carbon dioxide. Each study was given equal weight, except those using independent models. Five criteria were used in the analysis asking if the study was peer-reviewed, based on an independent impact assessment, based on a dynamic climate change scenario, based on economic scenarios, and if it estimates the marginal costs.

Analysis of Damages to Water Resources

Alexander et al (2005). Global observed changes in daily climate extremes of temperature and precipitation. Retrieved July 3, 2008 from Global Extreme Indices. Web site: http://secamlocal.ex.ac.uk/people/staff/dbs202/publications/2005/Alexander.pdf.

This study shows an upward overall trend in global precipitation. It illustrates that the greater capacity for warm air to hold higher amounts of precipitation causes more numerous extreme precipitation events.

Bernstein et al (2007). Climate Change 2007: Synthesis Report. Retrieved July 3, 2008 from Intergovernmental Panel on Climate Change. Web site: http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr.pdf.

This illustrates the science behind warming in areas and cooling in others.

Dadaser-Celik, Filiz and Heinz G. Stefan (December 2007). "Lake Level Response to Climate in Minnesota." University of Minnesota St. Anthony Falls Laboratory. Project Report Number 502. Prepared for Legislative Citizens Committee on Minnesota Resources: St. Paul, MN.

This source concerns the historical analyses of 25 Minnesota lakes. It involves a study to determine a correlation between climate variables and lake levels. Some of the lake level data reaches back to 1906. It was found that a majority of the lakes have seen increases in lake levels. Some of the greatest increases have occurred since 1990. A moderate correlation was found between precipitation and annual water levels. A weak correlation was found between air temperatures, dew point and lake water levels. A strong correlation was found between mean water levels in lakes in the same climate region, which suggests climatic influences on water levels. Conversely, a low correlation was found between mean water levels between all of the lakes studied (in different climate regions). This study shows that overall, there is an increase in water levels in the state of Minnesota, and that it could increase in the future.

Dadaser-Celik, Filiz and Heinz G. Stefan (March 2008). "Lake Evaporation Response to Climate in Minnesota." University of Minnesota St. Anthony Falls Laboratory. Project Report Number 506 Prepared for Legislative Citizens Committee on Minnesota Resources: St. Paul, MN.

This source analyzes the precipitation and evaporation rates for 6 Minnesota stations during the open water seasons. It finds that 3 stations report an upward trend in evaporation and

3 report a downward trend. Overall, a positive trend in evaporation was found for the last 12 months. The evaporation rates had a decreasing trend at 5 stations in the last 20 years. Besides evaporation, precipitation rates were found to be increasing at four out of six stations. Precipitation minus evaporation equals water availability. It was found that there was an increasing level of water availability, with a significant increase in the past 40 years. There was no reported correlation found between the three separate variables mentioned above. This study explains the findings of the work done in these author's analyses of 25 Minnesota lakes mentioned above.

D.P. Lettenmaier, D. Major, L. Poff, and S. Running. "Chapter 4; Water Resources." The Effects of Climate Change on Agriculture, Land Resources, Water Resources, and Biodiversity. The U.S. Climate Change Science Program, pp. 121-150. Available online <http://www.usgcrp.gov/usgcrp/default.php>.

The parent material and website of this source has further resources dealing with the current relationship between water and climate change.

This source examines the near term impacts of global climate change on water resources in the United States for the next 25 to 50 years. This piece of literature mainly examines variables including streamflow, evaporation, drought, precipitation, runoff and water quality. Minor focus areas include land use and ground water impacts. The sources of these studies are well cited, creating a positive waypoint for further research.

In the analysis of streamflow, trends from 393 stations in the US were plotted on maps and discussed with statistically significant increases reported in the central portion of the United States, which includes source stations in Minnesota (figure 4.7).

Evaporation rates are examined through several sources and the net decrease in these rates are discussed using varying hypotheses. For example, pan evaporation techniques are examined against theories such as the decreased amount of evaporation due to increased cloud cover.

Droughts are also discussed to occur more frequently in the West and Southwest and an overall wetter climate is discussed as occurring from studying data from 1915 to 2003. Droughts are not projected to affect the central portion of the United States.

An in-depth regional analysis is conducted for the central portion of the US, which includes Minnesota. Two separate studies have indicated an overall increase in precipitation in this region. However, studies examining Great Plains states to the near south of Minnesota show a reversal of this upward trend.

Runoff rates are explored by reporting USGS statistics on runoff for trends from 1901 to 1970. These are projected into the future, suggesting an overall increase in the central US. Runoff is further examined by region. The central portion of the US is likely to see an increase in runoff in the Upper Mississippi basin. However, there is conflicting information regarding the increase or decrease of water levels in the great lakes.

Water quality is also examined. Variables such as eutrophication from increased nutrient loads and increased temperature are discussed. Nutrient loading may occur from increased runoff and more highly variable heavy precipitation events. Decreased consistent precipitation could cause eutrophication from the increased levels of nutrients without adequate consistent flows. Also, nutrients create the conditions for algal growth. The existence of algae will lower the amount of dissolved oxygen due to consumption when photosynthesis is not occurring. The reported past changes in water quality have not been attributed to climate change. Land use is also discussed as a major determinant of water quality. A MN study is cited referring to high rates of chloride and phosphorous in urban and agricultural area waters respectively. These differing land use practices can impact runoff rates.

Additional variables are discussed besides surface water such as groundwater impacts, growing season impacts (which would positively impact tree growth), the increased amount of wildfires from increases in droughts in the South and Southwest, and increases in insects and disease from less harsh winters.

Lastly, this source examines observational methods from streamflow gauges, snow weight measurement techniques, evapotransporation methods and soil moisture characteristics. The source questions the outcomes of many of these models as climate change induced or from decadal or longer-term variability.

Groisman et al. (2001). Heavy precipitation and high stream flow in the contiguous United States: Trends in the twentieth century. Bulletin of the American Meteorological Society, 82, 219-246.

This study indicates that the Midwest is a region that is experiencing some of the highest increases of 1-day extreme precipitation events.

Karl et al. (1998). Secular trends of precipitation amount, frequency, and intensity in the United States. Bulletin of the American Meteorological Society, 79, 231-241.

Since 1990, a 10% overall increase in precipitation has occurred.

Klatter, H.E.; Vrouwenvelder, A.C.W.M.; van Noortwijk, J.M. (2006). Societal aspects of bridge management and safety in the Netherlands. In Proceedings of the Third International Conference on Bridge Maintenance, Safety and Management (IABMAS), Porto, Portugal, 16-19 July 2006. London: Taylor & Francis Group.

Bridge analyses by these Dutch researchers indicate that bridges and other infrastructure generally have a 50 to 100 year lifetime on average. If original functionality is preserved, bridges and structures may have extended lifetimes and would only retire when original use is no longer viable. These structures do degrade over time, as shown by in-depth maintenance analyses. Variables of degradation can include intensified use and the age of structures.

Maintenance is usually cost effective if it is only a small fraction of construction cost (0.66% in the case of the Dutch). Maintenance types can include “inspections, replacements, perfect repairs and lifetime extensions (also called partial repairs).” A bridge must be repaired when the probability of failure increases to an unacceptable level.

Although damages will occur worldwide, with the most damage in developing countries, the economic impacts of climate change will be specifically examined in the state of Minnesota. The direct lifecycle costs of a bridge include “construction, maintenance, and demolition.” Society and the environment also incur indirect costs. These may occur through time delays and environmental pollution (externalities). Maintenance costs can include costs such as coating steel with a protective layer. This application can have additional expenditures such as the necessity of using environmental barriers to prevent the spread of coating chemicals into the environment.

Maintenance costs include corrective and preventative costs. These may create direct costs such as the paying for the time of the workers. These may also create external costs such as the increased amount of time spent driving during detours.

Although intensified use and age are listed as important degrading mechanisms, Klatter et al. tout weather and environmental damage to be the most important variables for a bridge needing replacement. For example, chloride existing in the water can cause the corrosion of concrete bridges. In addition, steel can also be corroded by other environmental factors.

Construction, maintenance, deconstruction and external costs have been discussed above. Other costs associated with bridge damage include the price of paying inspectors to monitor bridges and structures to assess their integrity.

Kunkel, K, et al. (2003). Temporal variations of extreme precipitation events in the United States: 1895-2000. Geophysical Research Letters, 30, 1900.

Some of the data in this study show that the current increases in precipitation may be attributed to natural variations. Utilized National Weather Service Cooperative Observer Network (COOP) and NOAA performed analysis on precipitation events over the last 107 years. Data was compiled from the 1800s and digitized. Separate events were all analyzed in the study including 1,5, 10, and 30 day events at periods of 1.5, and 20 years. It was found that "extreme precipitation" events occurred in high frequency in the late 19^{th} and early 20^{th} century. Since greenhouse gases were not as prevalent at the turn of the century, the existence of a possible natural variability in extreme precipitation events is likely. However, data from 1895-1910 appeared odd and was subjected to manual interpretation and the information with the most irregular data was removed. This anomaly could have affected the final results regarding the frequency of the extreme precipitation events of this time period. Therefore, the irregularity of data could have created a discrepancy in the reliability of the conclusion that natural variation can explain the peaks in extreme precipitation events. The study is still being analyzed by researchers even after the information was published.

Panagoulia, D, & Dimou, G. (1997). Sensitivity of flood events to global climate change. Journal of Hydrology, 191, 208-222.

High volumes of water can destroy structures such as roads, bridges and levees.

Pielke, Jr., R.A., M.W. Downton, and J.Z. Bernard Miller (2002). Flood Damage in the United States, 1926-2000: A Reanalysis of National Weather Service Estimates. Retrieved July 3, 2008 from Environmental and Societal Impacts Group National Center for Atmospheric Research. Web site: http://www.flooddamagedata.org/flooddamagedata.pdf.

This source estimates the monetized damage estimates from National Weather Service records. This information is aggregated from separate datasets. Information from local regions was added to statewide data in some cases. Damage information spans from 1925 to 2000. However, the source indicates it is not to be used as a policy tool, due to inaccuracies. The inaccuracies are clearly spelled out in the abstract. Despite the flaws, the document contains useful estimate information to generate ideas. For example, flooding in Minnesota cost over $900 million in 1993 and $700 million in 1997.

Shuya, Abe, Watanabe Yasuharu, and Suzuki Yuichi (2005). Analysis of Flood Damage to Bridges on Saru River from Typhoon Etau. Monthly Report of Civil Engineering Research Institute, 631, 2-9.

Accumulation of debris may cause bridge pilings to wash out, and can lead to significant damages of these structures.

U.S. Army Corp of Engineers. (2003). U.S. Army Corp of Engineers Annual Flood Damage Reduction Report to Congress for Fiscal Year 2003. Retrieved July 3, 2008 from U.S. Army Corp of Engineers. Web site: http://www.usace.army.mil/cw/cecwe/flood2003/2003_Flood_Damage_Report.pdf.

This source provides information regarding flood reduction projects and spending by the USACE. Information presented includes average totals of money spent nation-wide for the last ten years, money spent by each state over the last ten years, flood damages incurred by each state

over the last 10 years and lives lost. For example, Minnesota spent a relatively low amount on flood reduction (compared to the national rising average) of $54 million between 1994 and 2003. In addition, in Minnesota over $131 million in damages were also indicated for the fiscal years of 1994 to 2003. The document compares the potential damages (avoided by mitigation) to the actual damages in a well-laid out graph. Oceanic storm damage and lives lost on average from flooding are also included in the summary. The source has very useful graphs and the damages are clearly laid out in a table format, both of which can be found in the appendix.