DISCUSSION DRAFT

A Unified Sea Level Rise Projection for Southeast Florida

December 2010

Prepared by the
Technical Ad Hoc Work Group

SOUTHEAST FLORIDA REGIONAL COMPACT CLIMATE CHANGE

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***The Cover:** A Fort Lauderdale home under "normal" conditions and inundated during an annual extreme high tide event (approximately 10 inches above the average high tide for the year on October 7, 2010) illustrating a true to life example of the potential impact of future sea level rise (photo credit: Paul Krashefski).

Acknowledgements

The Miami-Dade Climate Change Advisory Task Force and their Science and Technical Committee, Broward County Climate Change Task Force and their Science and Technical Subcommittee, the South Florida Water Management District, Florida Atlantic University and Army Corps of Engineers are acknowledged for their initiative to develop SLR projections for the Southeast Florida region. All workshop participants are recognized for using science to inform policy and thanked for their attendance, experience in this field and willingness to work toward a single regional SLR projection to use for planning purposes. Workshop participants and members of the SE Fl Regional Climate Change Compact Steering Committee are acknowledged for completing the pre-workshop survey which helped set the foundation for why having one projection was so important. This document was compiled by Nancy J. Gassman. Elizabeth Estes is thanked for her contribution to developing workshop materials and for supporting facilitation. Donald Burgess is acknowledged for his detailed note-taking. The following members of the Technical Ad Hoc Work Group wrote sections of this white paper Jayantha Obeysekera, Joseph Park, John Van Leer, Harold Wanless, and Glenn Landers. All members are thanked for their contributions to refining the document.

Executive Summary

Southeast Florida with its populous coastal counties, subtropical environment, porous geology and low topography is particularly vulnerable to the effects of climate change, especially sea level rise. At the October 23, 2009 Southeast Florida (SE Fl) Regional Climate Leadership Summit, the local diversity in sea level rise (SLR) projections was highlighted as a concern and a barrier to achieving regionally consistent adaptation policies. As expressed by the SE Fl Regional Climate Change Compact Steering Committee, the Climate Compact Counties (Monroe, Miami-Dade, Broward and Palm Beach) recognized the critical need to unify the existing local SLR projections to create a single regional SLR projection. Key participants in developing the existing projections and other local scientists knowledgeable in the areas of sea level rise and climate change were invited to participate as the Regional Climate Change Compact Technical Ad hoc Work Group (Work Group). Their objective was to work toward developing a unified SLR projection for the SE Florida region for use by the SE Fl Regional Climate Compact Counties and partners.

Through a series of facilitated discussions, the Work Group reviewed the existing projections and the current scientific literature related to SLR with particular emphasis on the impact of accelerated ice melt on projections. The Work Group recommends that the SLR projection to be used for planning purposes in the SE Florida region should be based on the Army Corps of Engineers (USACE) June 2009 Guidance Document. The projection uses Key West tidal data as the foundation of the calculation with a reference date of 2010 for sea level equals zero and two planning horizons including 2030 (USACE: 3-7 inches) and 2060 (USACE: 9-24 inches). The historic tidal and satellite altimetry data for the past few decades should be illustrated on the unified projection graphic to provide perspective on the projected rate of change of sea level. The Work Group recommends that the projection should be reviewed and possibly revised in two years (2012).

While the projection to be used for planning purposes looks out 50 years, a scientific narrative for beyond 2060 is also provided. This longer term vision describes the factors influencing sea level rise, the scientific challenges and areas where information is still needed. This section serves as a reminder that at any point in time in the coming decades, sea level rise is a continuing trend and not an endpoint. Potential impacts to south Florida are also outlined. The shorter term planning horizons are critical to develop the Regional Climate Action Plan and explore infrastructure options and design and adaptation strategies. As scientists develop a better understanding of the potential sea level rise at the end of the century, SE Fl community will need to adjust and adapt to the changing conditions.

A. Introduction

Local governments in the Southeast Florida recognized that the region with its populous coastal counties, subtropical environment, porous geology and low topography was particularly vulnerable to the effects of climate change, especially sea level rise. Several formed advisory groups to make recommendation on mitigating greenhouse gases and adapting to the inevitable effects of climate change. While the 2007 report of the International Panel on Climate Change proved to be a valuable source of the state of climate science for these advisory groups, the IPCC's sea level rise projections were failed to incorporate the contribution of melting ice and were felt to be inadequate. To address growing scientific evidence of accelerated melting ice sheets and absence of a sea level rise (SLR) projection specific for the Southeast Florida (SE Fl) area, a variety of entities developed SLR projections between 2008-2009 using the available science and their best professional judgment to guide local climate change planning efforts. At the October 23, 2009 Southeast Florida Regional Climate Leadership Summit, the local diversity in sea level rise projections was highlighted as a concern and a barrier to achieving regionally consistent adaptation policies. Following the summit, the four county commissions of the region (Monroe, Miami-Dade, Broward and Palm Beach) signed a compact to work together to address regional climate change issues. The SE Fl Regional Climate Change Compact Steering Committee (Steering Committee) comprised of representatives of the four Climate Compact Counties and the South Florida Water Management District (SFWMD), recognized the critical need to unify the existing SE Fl SLR projections creating a single sea level rise projection to use for regional planning purposes.

Key participants in developing the existing projections and other local scientists knowledgeable about sea level rise and climate change were invited to participate on a Technical Ad hoc Work Group (Work Group) to discuss working toward developing a unified sea level rise projection for the SE Florida region for use by the SE Fl Regional Climate Compact Counties and partners. Work Group participants included representatives of the Miami-Dade County Climate Change Advisory Task Force (MDCCATF), the Army Corps of Engineers (ACOE), Broward County Climate Change Task Force (BCCCTF), SFWMD, the University of Miami, National Oceanographic and Atmospheric Administration's Atlantic Oceanographic and Meteorological Laboratory (NOAA), and Florida Atlantic University (FAU) (see the list of participants).

Prior to the first workshop, the Work Group and the Steering Committee took a survey to outline the policy implications of a unified sea level rise projection for Southeast Florida. More than half of the respondents agreed with the following reasons for needing a unified sea level rise projection:

- To create a single baseline for regional adaptation planning;
- To establish a foundation for the Regional Climate Action Plan;
- To ensure consistency in regional and local infrastructure planning and design;

• To strengthen advocacy for the Regional Climate Compact efforts by speaking with one voice on this topic; and

• To demonstrate regional cooperation in technical matters.

The majority of respondents expected a local sea level rise projection to influence understanding regional risk to property, performing vulnerability analysis of critical urban and natural resources, developing water management and storm surge modeling scenarios, siting and designing public infrastructure, influencing policies related to land use and development, modifying water management operational protocols, influencing policies in the Comprehensive Plan, planning for transportation, reviewing regional adaptation options, identifying vulnerable populations and developing strategies for shoreline protection. While this information was presented to the Work Group to provide context for their efforts, their main objective was to use science to inform policy.

Table 1. Sea Level Rise Projections for Southeast Florida. Sea level rise (SLR) ranges are shown in inches rounded to the nearest half inch for four planning horizons.

Projection	Year Developed	Reference Year for Sea Level = 0	SLR range 2030	SLR range 2050	SLR range 2060	SLR range 2100
Historic-Key West (1920-2000) ‡		2000	2.5	4.5	5	9
Miami-Dade Climate Change Advisory Task Force	2007	2000	-	>18	-	36-60
Broward County Climate Change Advisory Task Force	2009	2000	3-9	-	10-20	24-48
South Florida Water Management District	2009	1990	-	-	5-20	-
Army Corps of Engineers June 2009 Guidance Document*	2009	2010	3-7	6.8 -17.5	9-24	19.5 - 57
Florida Atlantic University – Resilient Waters**	2009	2000	4.5-7	9-15	11.5-20	24 - 48

‡ Key West rate for 1910-2010 – 2.24 ± 0.16 mm/yr (NOAA) = 8.8 inches/century, calculated as a linear rate

*Calculations using Key West tide stations showing the intermediate to high range

** FAU Resilient Waters – Quadratic Equation using 2-4 feet as the 2100 projection

The existing local projections varied not only in the range of values for SLR but in most other components as well (Table 1). The initial review revealed that they were not developed at the same time and incorporated different scientific literature in their synthesis. They also differed in the year which represented a baseline for current sea level making comparisons of magnitude across the projections difficult. The local projects did not use the same planning horizons. Also while some were based on stated ranges, others used complex formulas to determine the values.

Over a period of several months from August – December 2010, the Work Group reviewed the existing projections, discussed the current scientific literature and developed the set of recommendations contained in this document for presentation and approval by the Steering Committee.

This document is organized into three main sections. The first is a discussion of the current state of the SLR science. The section on planning projections through 2060 outlines the Work Group's recommendation for a unified SLR projection for the SE Fl region. The final section looks beyond 2060 to describe the factors influencing SLR, the scientific challenges and areas where information is still needed. This section serves as a reminder that as scientists develop a better understanding of the potential sea level rise at the end of the century, SE Fl community will need to adjust and adapt to the changing conditions.

B. Scientific Summary

B.1 Sea level rise components

The causes of sea level rise resulting from climate change are complex. Factors affecting the ocean and its response to those influences are non-linear and not spatially uniform. In addition, positive and negative feedback loops exist that are not adequately understood. Generally, three main factors contribute to sea level rise; (1) steric effects which include changes to the physical state of water (2) eustatic effects which mainly encompass changes in the actual amount of water and (3) isostatic effects related to changes in the elevation of land masses.

During a period of warming climate, the volume of water in the ocean is primarily impacted by steric and eustatic factors mainly thermal expansion and volume added from changing precipitation, continental runoff and land based sources of melting ice. When heated, water expands. According to the IPCC, thermal expansion accounted for between 13-31% to the observed rate of sea level rise for the period of 1961-2003 (Bindoff et al. 2007). For the period of 1993-2008, 50% of the rate was attributed to thermal expansion (Cavenave et al. 2008). Land based sources of water are increasingly contributing to the change in observed sea level. Sources include glaciers and ice caps, the Greenland Ice Sheet and the Antarctic Ice Sheet In the last five years, the land-based water component of sea level rise explained 75-85% of the total increase (Cavenave et al. 2008).

Relative sea level takes into account not only changes in the level of ocean but the changes in the elevation of the land caused by uplift or subsidence, glacial rebound, erosion of the coast and tectonics. For example, parts of the Earth's surface are still undergoing a glacial isostatic adjustment (GIA) due to the deglaciation event following the last Quartenary ice age (Cazneave and Lovel 2010). South Florida land elevations are considered to be relatively stable meaning that the land mass is experiencing neither significant uplift nor subsidence. Preliminary results from the Continuously Operating Reference Stations, a network of permanent Global Positions System receivers that monitor vertical and horizontal land motion, suggest the land elevation in Key West is rising slightly at 0.24 mm/yr (1 inch/century) while other sites in Florida may be sinking at a rate of 2 inches/century (Maul 2008).

B.2 Historic sea level

On geologic time scales, sea level has been highly variable. Changing planetary forces such as tectonics, volcanism, solar dynamics, orbital variations, climate oscillations and anthropogenic forcing ensure that both local and global sea levels are dynamic. Cronin (1999) reviewed the work of Vail and Hallam which estimated historic sea level from paleoclimatic sediment reconstructions over the last 500 million years suggesting that sea level has been several hundred feet higher than present over a significant span of geologic time. More definitive paleoclimatic reconstructions from oxygen isotope records of Red Sea sediment cores (Siddall 2003) indicate that during glacial/interglacial cycles over the past several hundred millennia sea level has varied by roughly 360 ft (110 m) (see Figure 1).

A strong correlation between global temperature and sea level can be established by comparing paleoclimatic temperature reconstructions with changes in sea level changes. Figure 1 shows an overlay of roughly 400,000 years of global temperature based on Lake Vostok ice cores (Petit 1999), and sea level from Red Sea sediment cores (Siddall 2003), and provides two obvious conclusions: 1) As air temperatures rise and fall, so does sea level; and, 2) Rather sudden (geologically speaking) and large rises in sea level are not without precedent.

Since the last Glacial Maximum about 18,000 ago, sea level has risen about 360 ft (110 m) due to the loss of ice from land-based ice sheets (Houghton et al. 2001), during that period rates of sea level rise as high as 10 mm/yr (4 inches/decade) occurred. However, during most of the last 1000 years, sea level has been relatively stable, but as observed by the tide gage records, the rate of rise has been increasing over the 20th century.

B.3 Contemporary sea level rise

The rate of sea level rise averaged over the 20th century was reported as 1.7 ± 0.3 mm/yr (~1/16th in/yr) by Church and White (2006), while satellite altimetry results found a rate of 3.1 ± 0.7 mm/yr (~1/8th in/yr) over the period 1993 to 2003 (Cazenave and Nerem 2004). Independent assessment of the recent rate from tide gauge data finds a value of 3.2 ± 0.4 mm/yr over the time frame 1993 – 2007 (Merrifield et al. 2009), providing clear evidence of an increase in the rate of sea level rise.

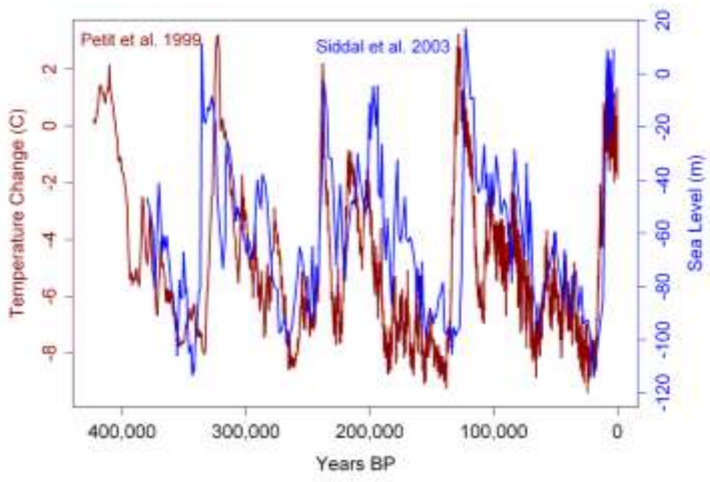

Figure 1. 400,000 Years of Reconstructed Temperature and Sea Level. Over geologic time, temperature (red) and sea level (blue) are well correlated.

B.4 Global sea level rise projections

The United Nations Intergovernmental Panel on Climate Change (IPCC) published the IPCC Fourth Assessment Report (AR4) in 2007 providing a comprehensive summary of scientific literature regarding sea level change mechanisms and projections (Bindoff et al. 2007). The AR4 report predicted a nonlinear acceleration of sea level over the 21st century. However, concern that increased meltwater contributions from Greenland and Antarctica were not included in the projections, coupled with observations that sea-level rise rates are already approaching the higher end of the IPCC estimates (Rahmstorf et al. 2007, Jevrejeva 2008) has lead to general consensus that these projections are too low and that glacial meltwater will increase levels and rates of SLR well above the IPCC projections.

At the national level, the National Science and Technology Council and U.S. Climate Change Science Program (CCSP) submitted a report to the Environmental Protection Agency (EPA) recommending "Thoughtful precaution suggests that a global sea-level rise of 1 m (3.3 ft) to the year 2100 should be considered for future planning and policy discussions" (CCSP 2009). However, the report was noted that large uncertainties in the glacial meltwater contributions required further scientific scrutiny.

Subsequent to the 2007 IPCC projections, the scientific community has continued to model and project sea level rise. Attention has focused on the glacial meltwater issue and in general, most contemporary projections are higher than the IPCC AR4 values. Table 2 lists projections at year 2100 from recent peer-reviewed publications indicating a movement towards increased acceleration of SLR.

Table 2. Sea level rise projections in feet at 2100 from recent peer-reviewed scientific publications.		
Author	**Min (ft) @ 2100**	**Max (ft) @ 2100**
Jevrejeva et al. 2010	1.97	5.25
Grinsted et al. 2009	2.95	4.27
Siddall et al. 2009	0.23	2.69
Vermeera et al. 2009	2.46	6.23
Pfeffer et al. 2009	2.62	6.56
Horton et al. 2008 [*]	1.54	3.28

*Both the IPCC AR4 and the semi-empirical sea level rise projections described here are likely to underestimate future sea level rise if recent acceleration trends in the polar regions continue.

B.5 Acceleration

Given the observation that sea level change is variable with respect to time, and the preponderance of evidence from recent ice loss and global climate models concluding that sea level rise is accelerating, one of the primary questions concerning projections is: what is the rate of change of sea level rise, i.e. what is the acceleration? This question is difficult to answer given the special and temporal variability of the ocean and the relatively poor observational sampling and accuracies[1].

The most comprehensive review of global accelerations was provided by Woodworth et al. (2009) noting that analysis of accelerations over the late 19th and 20th centuries by several authors are in general agreement, and that climate teleconnections[2] likely have a significant impact on the reported differences. The most geographically comprehensive quantification was reported by Church and White (2006) who found profound spatial variability across ocean basins, but did estimate a globally averaged value. A global analysis by Merrifield et al. (2009) over the period 1955-2007 based on 15-year windows found a positive acceleration since the late 1970's, and analysis of Greenland and Antarctic ice loss from

[1] Editorial Note: That the JASON-Topex/Poseidon has not resolved an acceleration is not surprising. The microwave ranging sensor has a resolution of 3.3 cm, which is the same order of magnitude as the annual drift. The results are averaged temporally to increase the accuracy to roughly 5 mm, but are spatially averaged to estimate basin scale rates, and the observational record is less than 20 years.

[2] Teleconnection generally refers to the linkage of seemingly unrelated climate anomalies over great distances. An example would be how El Niño, a decadal climatic and oceanic oscillation in the Eastern Pacific, impacts Florida weather and hurricane. These decadal oscillations occur in many ocean basics and may impact a variety of parameters from ocean temperature to atmospheric pressures and circulation patterns.

GRACE satellite data over the period 2002-2009 allowed Velicogna (2009) to estimate a global acceleration. Results of these analyses are shown in Table 3.

Table 3. Estimates of global sea level acceleration

Period	Acceleration	Author
2002 - 2009	0.17 ± 0.05 mm/yr^2	Velicogna 2009
1990 - 2009	0.12 mm/yr^2	Merrifield et al. 2009
1978 - 2009	0.09 mm/yr^2	Merrifield et al. 2009
1901 - 2000	0.013 ± 0.006 mm/yr^2	Church et al. 2006

B.6 Uncertainties

Uncertainty in developing sea level rise projections is associated with our limited understanding of selected natural and geophysical processes, the limited data with which to predict long term changes, the current limitations of global models and the lack of regional climate models. The traditional approach for projection of trends is to analyze historical data, in this case mean sea level, and estimate regression curves or statistical likelihoods in order to project the variables into the future. However, some inherent limitations exist with this approach. One problem is that historical data may not encompass enough samples to adequately represent long term trends. If the observations do span centuries, questions of measurement biases and inaccuracies dominate data collected prior the latter part of the twentieth century. Another issue is that many geophysical processes are statistically non-stationary, which simply means that the statistics change with time so that statistical averages, variances and regressions based on historic data may not correspond to future values.

A more general feature of geophysical processes is that they are complex, nonlinear dynamical systems. This is colloquially referred to as 'chaos theory', and in fact many climate and geophysical processes are properly considered manifestations of chaotic systems. These dynamics give rise to non-stationarity, tipping-points, emergence of new behaviors, and the breakdown of predictability into the future. It is one reason why accurate weather forecasts are limited to several days, and why highly certain climate forecasts are not tenable.

Yet another issue with geophysical forecasting based on limited sets of observed data are the presence of teleconnections. Tele-connections represent a sensitive dependence on seemingly unrelated variables and are increasingly recognized as important drivers of coastal oceanographic dynamics (Park et al. 2010). Analyzing historic data without consideration of these teleconnections may miss important system forcings and lead to erroneous projections. These feedbacks and links are not adequately represented in models, and, coupled with our lack of comprehensive sampling and understanding of these processes, climate models are currently not mature enough to adequately forecast these complex physical systems.

While uncertainties exist in accurately predicting sea level rise rates and acceleration, the evidence supports that that sea level is rising and will continue to rise even after mitigation efforts to reduce greenhouse gas emissions are successful at stabilizing or reducing atmospheric CO_2 concentrations. Planning projections for the near term (through 2060) are critical to begin adaptation planning for the SE Fl region. While current long term SLR projections provide some guidance for the potential future sea level rise (Table 2), sufficient time exists to obtain better scientific data and predictions before we need to extend the planning time frame beyond 2060.

C. Planning projections through 2060

C.1 Unifying Existing Local Projections

The development of the unified SE Fl SLR projection for regional planning purposes was a process requiring facilitated discussions over several meetings. At the first meeting of the Work Group, the pre-workshop survey results were reviewed focusing on the need for and application of a unified SE Fl SLR projection. Each of the existing local SLR projections was introduced revealing the method for development and the literature upon which it was based. After defining the characteristics of a good SLR projection, identified points of agreement related to projections, and discussed planning horizons for 2030, 2060 and 2100, the participants negotiated a projected SLR range for the first two time points. The group recommended additional discussion on the 2100 planning horizon and recommended that the final projection be reviewed and possibly revision in two years (2012).

At the next meeting, group members expressed concern regarding the process used in the previous meeting. While the final range of SLR values were informed by the current science, some members felt they were not defensible or supported in the text of the peer reviewed literature. A new process for developing a SLR projection was proposed using the quadratic equation (Church and White, 2007) and peer-reviewed literature values for expected acceleration of SLR. The group agreed to develop draft projections using this method and would compare the outcome against the Army Corps of Engineers guidance curves. The draft projections would use 2010 as the reference year for rising sea level.

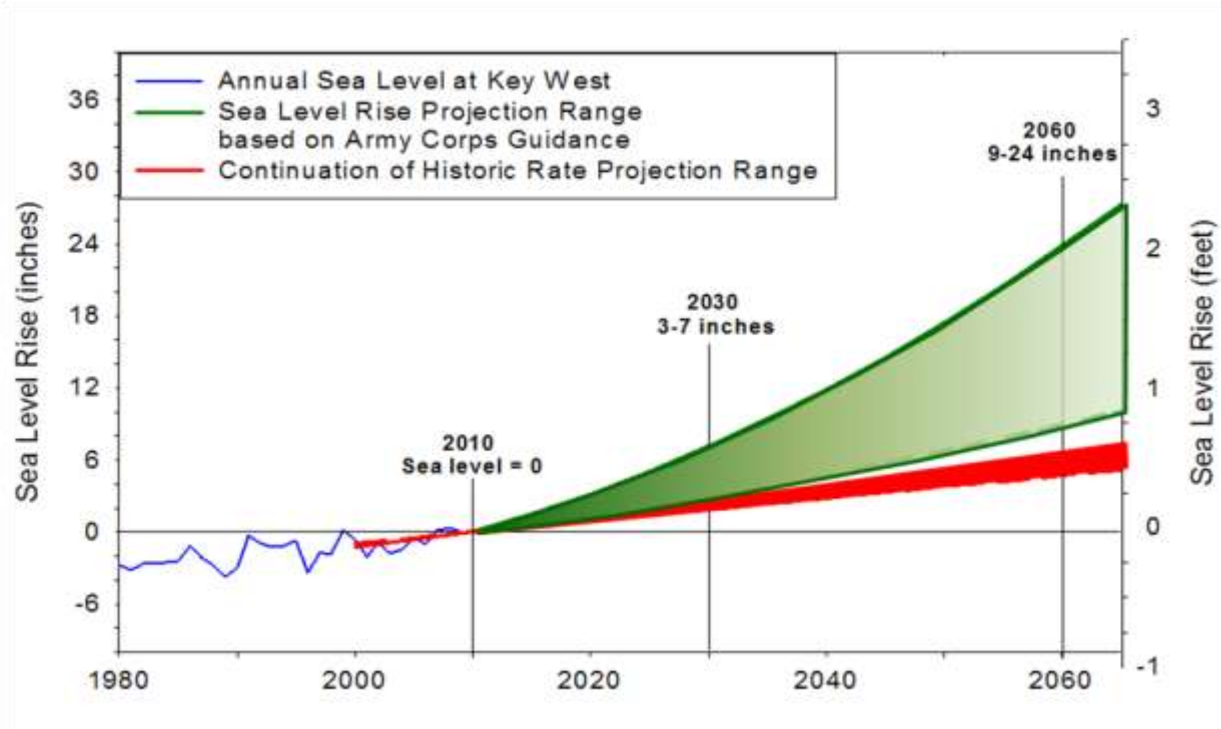

Figure 2 - Unified SE Fl Sea Level Rise Projection for Regional Planning Purposes - This projection is calculated using the USACE intermediate and high curves to represent the lower and upper bound for projected sea level rise. The historic Key West tidal data shows current trends in the recent past. The recent rate of sea level rise from tidal data and altimetry data is extrapolated to show how historic rates compare to projected rates.

Work Group member, Barry Heimlich, developed the calculations for the following meeting (see meeting minutes for Oct 15). After thorough review and debate, the Work Group Members agreed that the US Army Corps of Engineers Guidance Document curves (USACE, 2009) offered a reasonable and defensible projection to use in the 2030 and 2060 time frames (Figure 2). The Work Group agreed that the curves should be illustrated through 2060 with historical tidal data and extrapolated historical rates to provide perspective.

(Include a Table of Acceleration Rates by Decade from 2010 through 2060 ?)

C.2 Sea Level Change Projections Using USACE Methodology

The U.S. Army Corps of Engineers (USACE) sea level change projections are produced in a multiple scenario format with three projections: a high rate projection, an intermediate projection, and a projection assuming a continuation of the historically measured rate. The USACE sea level change projection methodology is summarized in Engineering Circular (EC) 1165-2-211 and was derived from Responding to Changes in Sea Level: Engineering Implications (NRC, 1987). The Circular is applicable to all USACE Civil Works activities except Regulatory actions. Potential relative sea-level change must be considered in every USACE coastal activity as far inland as the extent of estimated tidal influence.

The method of EC 1165-2-211 is based on the sea level rise curves produced in *Responding to Changes in Sea Level: Engineering Implications* (NRC, 1987). The EC contains the following changes from the NRC (1987) projections:

1.) Changes in the formula to allow the user to select a specific origin year (allows flexibility to start the projection on a given year).

2.) The EC uses only two out of the three original NRC curves. NRC curve III (highest rate) and Curve I (lowest rate) are retained while curve II, an intermediate rate, is dropped. The EC adds a new projection, continuation of historic rate, to form the lowest of the three projections.

3.) Changes in the formula to allow the user to specify the historic relative sea level rise rate appropriate for the user's area of interest. In the NRC's (1987) original work, the rate of sea level rise was fixed at 1.4 mm/year.

C.2.1 Projection Format

Planning studies and engineering designs are to consider the entire range of possible future rates of sea-level change. The EC is built on the assumption that the range of possible future rates of sea level rise is bracketed by the "low" (historic) and "high" rate projections.

High - The high rate projection is assumes that in addition to the historic rate of sea level rise that there is a major acceleration in the rate over the next century. This high rate exceeds the upper bounds of IPCC estimates from both 2001 and 2007 which most scientists agree did not adequately address the potential rapid loss of ice from Antarctica and Greenland.

Intermediate - The intermediate rate projection assumes that in addition to the historic rate of sea level rise that there is a moderate acceleration in the rate over the next century. The intermediate projection is not a "most probable" projection. In fact, the projections are not probabilistic in nature and are all assumed to be plausible.

Historic - The historic projection uses a locally derived historic rate of sea level rise that is extrapolated into in the future without any change in the existing rate of sea level rise.

C.2.2 Data Inputs

The only data required for calculation of a projection using EC 1165-2-211 is the relative sea level change rate at the location of the desired projection. For the purposes of the SE Fl unified SLR projection, the relative sea level rise rate at Key West (2.24 mm/year, NOAA, 2010) was used .

C.3 SLR Projection Use by the Compact Counties and Partners

The ranges of SLR presented in this section for the 20 and 50 year planning horizons are intended to be used for planning purposes only. They will allow the SE FL Regional Climate Change Compact Counties and their partners to explore adaptation planning scenarios which will result in the SE Fl Regional Climate Change Action Plan. The regional plan will guide future policy and adaptation strategies on transportation, the built environment and land use.

D. Sea Level Rise Projections beyond 2060 - An Exercise in Divergent Options

In the context of climate change, adaptation is defined as planning for the inevitable and/or predictable impacts of these changes, especially sea level rise. Under the "business as usual" scenario, we can estimate both the potential sea level rise and the possible impacts of it to our community for the near term planning horizons. Current and future mitigation of greenhouse gasses through policy actions, behavioral and cultural change and reduction of the burning of fossil fuels will alter the future of impacts climate change on our planet. In addition, the emerging understanding of reinforcing climate-change feedback loops will influence scientific monitoring, climate modeling and predictive tools into the future. The questions remain of how soon before significant sea level rise becomes disruptive to our south Florida communities and how fast should we expect sea level to rise throughout this century. The following section discusses how various aspects of mitigation and scientific understanding can create alternative futures and why current action is needed to address past practices and influence future policies and plans.

D.1 Future Impacts of Current Emissions – Why Historic SLR Curves Under Predict Future Sea Level Rise

The past is no longer a good predictor of the future in relation to SLR (Figure 3). Historical trends do not account for the substantial inertia in the earth's climate system caused by greenhouse gasses such as carbon dioxide (CO_2) with long residence times. Today's carbon dioxide concentrations (382ppm) are 100ppm higher than the pre-industrial (interglacial) maximums. The equilibrium temperatures in the past interglacial periods were thus achieved with much lower greenhouse gas concentrations. We should reasonably expect higher equilibrium temperatures after the climate system has finally adjusted to the much higher greenhouse gas concentrations of today. CO2 has an atmospheric residence time of hundreds of years so the carbon burned by our immediate ancestors is mostly still at work in the atmosphere (Archer 2005; Caldeira and Wickett 2005). We have yet to discern the impact of the current generation's emissions on the global climate system which will be manifested in the future. Continued CO2 and other greenhouse gas buildup greatly complicates future reduction and might leave the planet at the mercy of future "geo-engineering efforts" with as yet unknown side effects.

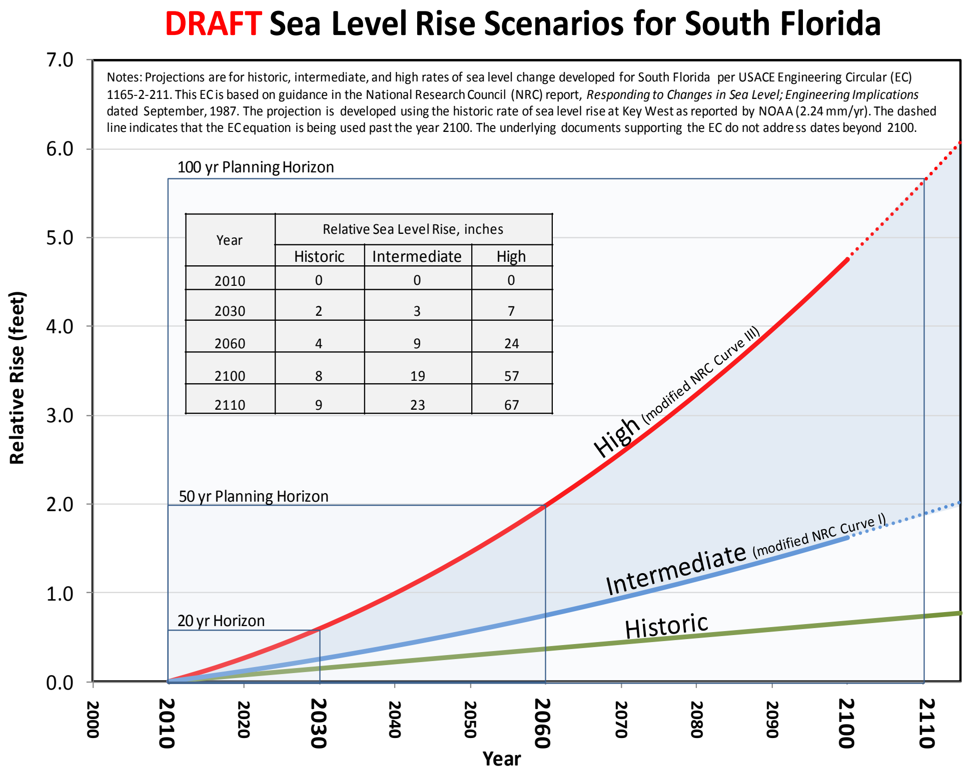

Figure 3 - USACE Sea level Rise Projection for the South Florida Region through 2110 – With time, the intermediate and high projection increasingly diverge from the historic rate of rise.

Methane concentrations are 1755ppb compared to 700ppb pre-industrial interglacial maximums. Methane has lower concentrations but is about 23 times more powerful as a greenhouse gas than CO2 accounting for about 40% of the greenhouse warming compared to CO2. Fortunately, methane has a short ten year half life in the atmosphere. Unfortunately, it converts to CO2 adding its atmospheric concentration builds up.

D.2 Feedback Loop - Warmer Atmospheres Hold More Water Vapor

For each degree C of global warming, the atmosphere can hold an additional 7.5% of water vapor (follows from the Clausius-Clapeyron Equation). Water vapor increases the greenhouse effect and growing concentrations will result in a 2% increase in global precipitation (Held and Soden 2006). The current warmer atmosphere has nearly 5% more water vapor compared to pre-industrial levels. The eruption of Mt. Pinatubo in 1991 produced the last transient global cooling (-.5 degree C) and drying event. The water vapor reduction was responsible for a significant portion of the global cooling observed, which validated the water vapor feedback mechanism in Global Climate Models.

D.3 Glacial Earthquakes Connected to Warm Water Melting

Glacial earthquakes were discovered in 2003 (Nettles and Ekstrom 2010). Lamont-Doherty Earth Observatory scientists review of the phenomenon shows the locations of 13 glacial earthquake sites in the major glacial outlet fjords on both coasts Greenland (*ibid.,* Figure 2). They present convincing connections between the calving events at Helheim Glacier and ensuing glacial earthquakes generated by subsequent rapid seaward glacial movements of the Helheim Glacier extending at least 20km into the inland icecap. Nettles and Ekstrom show the locations of 14 teleseismic detections along the Antarctic coast (*ibid.,* Figure 9). These earthquakes are well removed from tectonically active plate boundaries and likely correspond to glacial earthquakes at the glacial ice outlets along the Antarctic coast. Next summer there will be an oceanographic cruise around the entire Antarctic Continent to get as close as possible to these outlets to document how warm and salty these waters have actually become and what the CO^2 flux out of the Arctic Ocean is.

D.4 Scientific and Economic Support for Immediate Emissions Reduction

A strong consensus exists among climate, ice and sea-level scientists that the global atmosphere will continue to warm, that the ocean waters will continue to warm and expand and that glacial ice and ice sheet melt will continue to accelerate through this century (IPCC 2007). Sea level will also continue rising at an accelerating rate, leading to significant coastal consequences.

In May 2008, 1733 U.S. Scientists and Economists, including Nobel Laureates in Chemistry, Economics or Physics, NAS, NAE and IPCC lead authors signed a letter titled “Call for Swift and deep cuts in Greenhouse Gas Emissions.” This letter called upon “U.S. Policy Makers to put our nation onto a path today to reduce emissions on the order of 80% below 2000 levels by 2050. The first step on this path should be reductions on the order of 15-20% below 2000 levels by 2020, which is achievable and consistent with sound economic policy.” A delegation of 70 of these scientists and economists personally presented signed copies of this letter to members of the United States Congress on Capitol Hill in Washington, D.C in May, 2008. While the scientifically documented need for the above actions are even greater in 2010, the carbon interests have succeeded in “turning back the clock” and have a fresh group of senators and representatives who now claim that they “unsure” if global warming exists and deny significant human involvement in it.

D.5 Only Germany Met Kyoto Protocol Promises

Greenhouse gas concentrations in the atmosphere are still increasing at 2.5% per year since the Kyoto Protocol was signed. The rate nearly doubling since the 1970s due primarily to the accelerating burning of fossil fuels, especially coal (Hansen et al 2008). Only Germany met and exceeded its agreed 6% target reduction by an additional 2%, with an aggressive solar, wind and efficiency campaign. Their national efforts created 250,000 German jobs (especially in the depressed former East Germany) and made Germany a world leader in efficiency methods and renewable energy technology required for a sustainable global future. In the past two years, China has become the volume leader in wind and solar devices but lags Germany in quality and high performance and complete supporting product lines.

Hansen et al (2008) have laid out a road map to bring CO_2 below 350ppm, which is realistic economically and scientifically and follows a similar path to the one initiated by Germany.

1. Quick Coal Phase-Out Necessary - All coal emissions & soot halted in 20 years

2. No Unconventional Fossil Fuels, like: Tar sands, Oil shale, Methane hydrates

3. Don't Pursue Last Drops of Oil in Polar Regions, Deep Ocean or Pristine Land

The first challenge is that fossil fuels are the cheapest energy because they are subsidized and do not pay their global costs, including sea level rise relocations. The solution is to raise the price of carbon. While regulations will be required to achieve the carbon dioxide goal, the price of carbon would provide enforcement. In addition, technology development will be needed to use new sources of fuel but this is driven by the certainty of carbon price so the governments' role is limited to the goals allowing the markets to make technology choices.

NJG comments: Science or Policy Discussion?

How do Hansen et al (2008) achieve these Goals? <u>Fee</u> & <u>Green Check (Dividend)</u>

1. Fee Applied at First Sale/Port of Entry, Covers all Oil, Gas, Coal ◊ No Leakage

2. Fee Specified: No Speculation, No Volatility, No Wall Street Millionaires at Public Expense by "smart guys" who "game the system" again.

3. Other Merits: Only Potentially Global Approach; Simple, Honest, Can be Implemented quickly; Market Chooses Technology Winners; Achieves the Most Efficient & Largest Carbon Reductions (World wide we are all on the same economic playing field as well as the same planet)

4. Dividends distributed to People and Business Implementing Sustainable Solutions like the Feed-in-Tariffs put forward by the Green Party in Germany.

<u>What would be the likely Outcome from such a Fee and Green Check Program?</u>

According to the Economists who signed the above letter, the result of such a program would be massive job creation in sustainable industries following along the lines clearly demonstrated by Germany. It would also help prepare the USA for the "down side" of "Peak Oil", while limiting our balance of payments deficit, and simultaneously delaying and reducing the enormous adaptation and mitigation costs due to future sea level rise, which are outlined below in the Consequences Section. To achieve the intermediate SLR curve, we would have to take all of the measures outlined above or their equivalents.

Outlined above are the actions needed to slow this progression and reduce the social and economic consequences of continued procrastination and inaction. Our response must go far beyond green washing.

What's Really Happening in the Business World? Business as Usual

1. Tar Sands Agreement with Canada Pipeline planned to transport oil

2. New Coal-fired Power Plants Rationalized by 'Clean Coal' mirage

3. Mountaintop Removal Continues Diminishes wind potential of mountains

4. Oil & Gas Extraction Expands Arctic, offshore, public lands

D.7 Warming of Oceanic Waters Contributes to Ice Melt

Increased global heat storage in upper 2,000 meters of ocean was 0.77 +/- 0.11 W/m^2 during 2003-2008 based on ARGO data. Knowledge of Earth's energy imbalance is improving rapidly as ARGO data lengthens. Data must be averaged over a decade because of El Nino/La Nina and solar variability. This energy imbalance is a smoking gun for human-made increasing greenhouse effect (von Schuckmann et al. 2009). Some of this newly stored heat will almost certainly find its way to high latitudes via ocean currents, like the 8 Sverdrup (1 Sverdrup=million metric ton/second) Warm and Salty Norwegian Current, and contribute to future pack ice melt and ice sheet collapse.

Since the mid 1990s, ice sheet melt in Greenland has accelerated as a result of warming atmospheric conditions (Zwally et al. 2002). Over the past decade, scientists have begun to fully appreciate that much of the rapidly accelerating melt on the Greenland and Antarctic Ice Sheets is the result of warmed ocean water moving in under the deep outlet glaciers in fjords in Greenland and beneath the larger Ice Shelves in Antarctica. For the past century and most dramatically since the 1980s, the layer of warm salty North Atlantic water has been warming and thickening, which is found underneath the pack ice. This layer of warm salty Atlantic water was originally reported by Fridtjof Nansen, under the Arctic Ocean pack ice, in the 1890s following the Fram Transpolar Drift. In 2007, the TARA transpolar ice draft repeasted the Fram drift and determined that this layer had thickened by 100m and warmed by 0.5 degrees C (Prof. Jean Claude Gascard). Because of diminished ice cover and stronger winds, TARA took in only half the time complete the same Fram drift track.

As this warmed subsurface ocean water has continued to penetrate the Arctic Ocean, it accelerated summer pack ice melt from below and began the melting beneath the outlet glaciers of the Greenland Ice Sheet (Holland et al 2008). Since 1990, there has been a dramatic reduction in the areal extent, thickness and thus the volume of summer pack ice in the Arctic Ocean, according to data posted on the National Snow and Ice Data Center (NSIDC) website (http://nsidc.org/). The growing areas of open water which in turn has resulted in accelerated warming of the open areas of the Arctic Ocean. Thinner ice is more easily broken up by waves, which grow larger in the expanded fetch across growing areas open water. Thin ice is easily rafted, with one floe slipping on top of another, which in turn creates more open water. Winter storm tracks, which used to cross the North Atlantic from Southern Greenland to the Norwegian Coast, are now tracking further northward and growing more intense. Meteorologists have coined a name for this new class of fast developing, intense winter storms called "Arctic Bombs". New wind patterns are emerging, such as the "Arctic Dipole" pattern reported by NSIDC may reasonably be expected, which may account for the rapid TARA drift which was roughly twice as fast as the Fram Drift a century ago and the diminishing pack ice in the East Greenland Current.

With all the open water in the Arctic Ocean, this ocean is now capable of generating abundant warm water within the Arctic Ocean itself. As the thickness and extent of Arctic Pack Ice has diminished, a radical change in albedo from 70 to 90% reflection of solar energy (depending on snow cover) on an ice-covered ocean to the 80 to 90% heat absorption by an ice- free ocean has increased the surface temperature of the Arctic Ocean dramatically (4-5 degrees Celsius) during summers (NSIDC).

This warmed Arctic Ocean water is now accelerating melt of remaining pack ice and adding to the warmth of the East Greenland Current, which is penetrating outlet Greenland's fjords and accelerating melt of outlet glaciers from the Inland Ice Sheet, like Kangerdlugssuaq and Jakobshavn. Holland et al (2008) have recently observed accelerations of the Jakobshavn Isbrae in west central Greenland, which coincide with the appearance of warm salty waters, which have entered the Jakobshavn Fjord from offshore. Four degree C salty waters of Atlantic origins have entered Sermilik Fjord by way of the Irminger current just offshore (also see Nettles and Ekstrom, 2010). Similar accelerations of Helheim Glacier into East Greenland's Sermilik Fjord have been reported in 2010 by Woods Hole Oceanographic Institute scientist Fiamma Straneo and colleagues.

D.8 Reinforcing Feedbacks Are Driving Irreversible SLR Acceleration

Reinforcing feedbacks are documented for climate warming, accelerating ocean warming, accelerating glacier and ice sheet melt (on both Greenland and Antarctica), resulting warming and thawing of Arctic tundra and permafrost, and associated accelerating release of methane and carbon dioxide from organic decay in melted tundra and melting methane hydrates. These feedback mechanisms have led to a nearly irreversible condition in which sea level rise will continue accelerating through this century and beyond.

D.9 Past and Future Sea Level Rise

The climate, ice and sea level scientific communities generally agree that atmospheric and oceanic warming will continue and that there will be acceleration in glacial and ice sheet melt through this century and beyond. As a result, communities must plan for acceleration in global sea level rise through this century and beyond.

Recent literature projections for sea level rise by 2100 are were summarized by Heimlich in Figure 4 and in Table 2. The +2.5 to +6.5 feet range reflect the various trajectories climate change may follow depending in part on the as yet undeclared reduction in greenhouse gas emissions. The low projections assume an immediate dramatic decrease in the use of fossil fuels on a global scale outlined above – something that is not yet happening and not on the visible horizon.

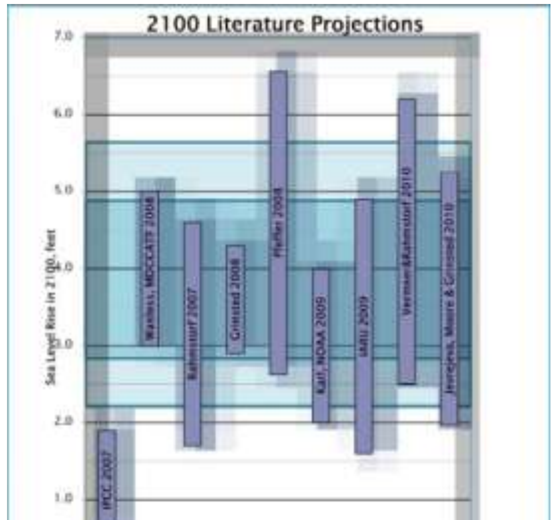

Figure 4 - Literature Projections Sea Level Rise in 2100. (Heimlich et al., 2010)

The intermediate and high sea level rise projections used as near term planning SLR projections should be considered a minimum range. While the projections are illustrated as gradual curves, the rapid collapse of one of more ice sheets could lead to a rapid pulse of sea level rise. Sea level rose from -120 meters (-420 feet) at the end of the last glacial maximum to the present level in a series of rapid 1-10 meter rises separated by periods of relative stability (Anderson and Thomas 1991; Anderson et al. 2004; Bard et al. 2010; Blanchon and Jones, 1995; Dominguez and Wanless 1991; Florea and Vacher 19xx; Jarrett et al. 2004; Locker et al. 1996; Rodriguez et al. 2000). With the severe destabilization of climate and ocean temperatures resulting from the last 150 years of human-induced global warming, one or more pulses of ice collapse and rapid sea level rise could be expected to occur within the coming century.

From the perspective of natural history, there is nothing special about where sea level is at present. During the prolonged interglacial 130,000-120,000 years ago or the brief warm period 82,000-80,000 years ago, sea level rose past the present level to about +20 and +8 feet respectfully – at a rate that no coastal deposits (barrier islands, tidal deltas, reefs, tidal flats, coastal wetlands, or deltas) formed at or near present level (Dorale et al. 2010; Wanless et al. 1989).

Little uncertainty exists that sea level will continue to rise at an accelerating rate through this century and beyond (IPCC, 2007). This is virtually guaranteed by the heat now stored in the world's oceans from widespread and significant warming during the last century, continued and accelerating build up of greenhouse gasses in the atmosphere including (Tans, 2008), accelerating loss of the volume of Arctic summer pack ice, and increased melting of organic-rich Arctic tundra and permafrost (resulting in dramatic increases in the decay-release of carbon dioxide and methane).

Increased westerly wind in the Southern Ocean results in increased upwelling of warmed water and consequent penetration of this warmed water under the Antarctic Ice Shelves. There is new evidence of CO_2 release from the freshly upwelled water, and, thus the Southern Ocean is also becoming a source for increased introduction of greenhouse gasses into the atmosphere.

D.9.1 Sea Level Rise Uncertainty for 2060 and Beyond

The uncertainties for the latter part of the coming century are described below as a series of questions:

- How much faster will the Ice Sheet and glacial ice melt be? How much faster will sea level rise acceleration be? In other words, will we be looking at a 3-foot rise, a 6-foot, or more by the end of the century?

- Will there be additional collapses of Ice Sheet sectors like Larsen B (the size of Delaware) which collapsed in a few days in March 2002? Following Larsen B's collapse, Crane Glacier was no longer buttressed by the vanished Larsen B ice shelf and began to thin and accelerate into the Antarctic Ocean. Is this the mechanism which has been so clearly seen in the geological record, triggering rapid pulses in sea level rise during periods of de-glaciation? Pine Island glacial outlet to the West Antarctic Ice Sheets is now rapidly thinning and is of special concern.

- How much with the Florida Current and Gulf Stream be impacted by climate change? Warming in the Arctic reduces the temperature gradient across the Arctic atmospheric front (which supports the Jet Stream) which in turn reduces the strength of the mid-latitude westerly winds. The reduced westerly wind stress reduces the wind stress curl driving the North Atlantic Gyre. Such a reduction would result in reduced flow of the Florida Current and Gulf Stream east of Florida, which would result in a regional elevation in sea level along the Gulf and Atlantic coasts of Florida.

- Will humanity quickly and dramatically reduce the levels of greenhouse gasses in the atmosphere so that ocean warming will stop and gradual ocean cooling can begin (Hansen et al., 2008)? Because of the long residence time of carbon dioxide inputs into the atmosphere (Archer, D., 2005, and Caldeira, K., and Wickett, M.E., 2005), just reducing the rate of input of greenhouse gasses into the atmosphere will not be sufficient to stop the warming of the atmosphere and the ocean, and, thus, will not be sufficient to slow ice melt and sea level rise acceleration.

D.10 The Consequences of Sea level Rise in South Florida

D.10.1 1-2 Feet of Sea Level Rise

The first problems South Florida will experience are decreased ability to drain flood waters from low-lying inland areas, increased frequency of sea-water flooding of low-lying coastal areas, increased storm surge damage [occurring now]. Many of these have initiated with the 9 inches of sea level rise we have had since 1930, and they will become increasingly severe or complete with sea level rises of 3, 4 and 5 feet.

- *Loss of Inland Drainage:* The South Florida Water Management District says that with just a further 8 inches sea level rise, 65% of the water control structures will fail to function as designed [2028-2053]; with a 0.5 meter (1.5 feet) rise, the SFWMD expects 82% of the structures to fail [2050-2097]. As these structures fail, they will also become unable to provide drainage for low-lying areas inland or prevent of salt water intrusion.

- *Decreased rainfall:* Much of peninsular south Florida's rainfall is from convection heating of the humid air over our low-lying saline and freshwater wetlands from May/June to October/November. As these areas are inundated this source will diminish resulting less rainfall to peninsular Florida. This will diminish freshwater addition to the surface and ground waters making it more difficult to maintain an effective freshwater head (elevation) to prevent saline intrusion and to provide the necessary water for the Everglades, human consumption, landscape maintenance, agriculture and industrial uses. This will become most dramatic with 4-5 feet of sea level rise.

- *Saline intrusion:* Freshwater levels need to be held one to 1.5 feet above mean sea level to prevent saline waters from moving inland during the dry season. If the fresh groundwater levels are raised much, low-lying areas along the western parts of the counties will become seasonally to permanently flooded. If this differential elevation (freshwater head) is not maintained we will more quickly loose our ability to pump freshwater from the local Biscayne aquifer.

- *Increased stress on freshwater resources from nuclear power plants:* With inundation of our coastal wetlands and penetration of saline waters inland, our surface freshwater resources and the connected freshwater in the unconfined Biscayne aquifer will diminish limiting the freshwater resources for the Everglades, human consumption, landscape maintenance, agriculture, and industrial use (Wanless et al. 1994). The proposed additional nuclear power plants for Turkey Point in south Miami-Dade County necessitate intense use of reclaimed wastewater, water that will be needed for maintenance of an adequate freshwater head for the Everglades (to prevent further saline intrusion) and other human, agriculture and industrial use.

- *Inundation of low-lying filled lands:* We are already seeing inundation of 'land' that was created by filling wetlands (e.g. western side of Miami Beach) and bay bottom (islands in northern Biscayne Bay). The continued gradual subsidence resulting from dewatering compaction of the bay-bottom muds, which were used for fill, have put much fill land below design elevation and subjected to increasingly frequent inundation by exceptional tides and minor storm tides. This will increase in frequency and severity through time.

- *Increased mosquito stress and disease vector habitats:* Over the past century, drainage has been established for low-lying coastal and inland wetlands so as to minimize areas of ponded water stagnation. With rising sea level, many new areas of frequent, prolonged, undrained water ponding will appear and will become stagnant mosquito breeding habitats. This will be a constantly changing mosaic on sandy barrier islands, in the Florida Keys, on the mainland coast in the low-lying western portion of the counties, and from new areas of ponded undrained water.

- *Increased daily tidal range on mainland coasts:* Rising sea levels will extend areas of daily flooding across present mangrove and freshwater wetlands, increasing the area of daily tidal flooding within the enlarged coastal bays, thus increasing the tidal prism. This will result in stronger currents through seaward channels and inlets through barrier islands, the Florida Keys, and mud banks. Stronger currents will mean that present inlets will enlarge and new inlets open by storm surges will be more likely to remain open. As a result mainland shorelines will experience larger (less dampened) daily tidal range – in effect an additional rise of high-tide sea level.

- *Increased flooding frequency, intensity, and damage from storm surges:* Rising sea level will result in an exponential increase in damage from future hurricanes as storm surge power reaches further inland, storm flooding reaches higher levels, more inundated seaward barrier islands and wetlands become less and less effective obstructions to storm surge penetration. With a 2-3 foot rise in sea level [as early as 2060-2077], nowhere in Monroe, Miami-Dade and southern Broward County will be safe from serious storm flooding and surges from major Hurricanes.

- *Loss of access to home and commercial insurance coverage and mortgage resources (truly an underwater mortgage):* Before a further two-foot rise in sea level is reached, increased risk will have forced commercial insurance companies and the State to have withdrawn coverage from large areas of low-lying south Florida and will have forced the Federal government to have curtailed flood insurance and FEMA underwritten reconstruction.

- *Abandonment of lower elevation suburbs* (most western and southeastern portions of mainland and lower portions of islands): Low-lying residential, commercial, and industrial areas subject to more frequent flooding, increased storm surge damage, increasingly compromised infrastructure functionality, and/or loss of insurance coverage and mortgage accessibility will be gradually to abruptly (Katrina style) abandoned. With this will come demand for relocation costs, costs for cleaning abandoned polluted land, and loss of tax revenue base.

- *Choices:* South Florida will have to make very significant choices between to what extent to spend money and resources on (a) defenses and rebuilding infrastructure to try to protect against rising sea levels and (b) assisting in personal, commercial and governmental relocation. Importantly, levees and dikes will not prevent inundation of the extremely porous and permeable limestone and sand substrates beneath South Florida without expenditure of immense amounts of pumping energy.

D.10.2 3-5 Feet of Sea Level Rise

With a sea level rise of 3, 4 or 5 feet, all of south Florida will be severely impacted and a difficult and increasingly risky place to live.

- *Abandonment of Barrier islands:* Severe coastal erosion, persistent flooding throughout most of the islands, high risk to life and property from storm surges, and loss of insurance will force abandonment of the sandy barrier island throughout south Florida (and the world).

- *Inundation of moderate elevation suburbs and industries:* With a 4-foot rise of sea level, only 62 per cent of Miami-Dade County land (east of Krome Avenue) is above mean high water level. Of the remaining land, over 80 per cent is less than 4 feet above mean high water and with a non-functional infrastructure, lacking of spatial connectivity, extremely prone to severe loss of life and property by even minor storm surges, and loss of insurability. These southern counties will be diminishing as a population center and with diminishing business opportunities and tax base.

- *Loss of freshwater resources:* Between 3 and 4 feet sea level rise, the fresh surface water and connected unconfined Biscayne aquifer will be lost to sea water intrusion throughout the Everglades north to Palm Beach County and beneath the coastal limestone ridge north to northern Broward County. Fresh surface or well water to cool nuclear power plants will be lost.

- *Infrastructure collapse:* Major disruption and/or loss of infrastructure, sewage treatment capability, and functionality of airports, port facilities, tunnels, and roads.

- *Increasingly frequent flooding and damage from storm surges:* Because of significant sea level rise, large portions of south Florida will become increasingly frequently flooded and increasingly frequently and more severely damaged by storm surges. With a 4 foot sea level rise, storm surges will funnel up the newly inundated Everglades Estuary providing storm surge risk from the west side of Mimi-Dade, Broward and Palm Beach counties.

- *Massive abandonment and collapse of financial structure:* Between 2 and 5 feet of sea level rise and because of the above listed risks and disruptions, the southeast Florida counties will experience massive and widespread abandonment by individuals and businesses, the stresses and costs of relocation, and collapse of financial structure with widespread defaulting on home and commercial loans and bond obligations.

- *Severe marine pollution:* Leaching and erosion of inundated and abandoned landfills and polluted industrial areas has the potential to result in severe marine pollution to our new shallow marine environments. It is imperative that funds are planned for and set aside for the cleaning of polluted areas and the sealing or relocation of contaminated landfills and traditional and nuclear power plants.

- Massive abandonment and relocation, defaulting on home, commercial and bond obligations

E. Recommendations

The following are recommendations of the Technical Ad hoc Work Group for consideration by the SE FL Regional Climate Compact Steering Committee to be used by the Compact Counties and their partners to develop the Regional Climate Change Action Plan.

a. The SE Fl Unified SLR Projection should be based on the Army Corps of Engineers (USACE) June 2009 Guidance Document using Key West tidal data as the foundation of the calculation and referencing the year 2010 as the date for sea level equals zero.
b. This projection should be used for planning purposes only with emphasis on planning horizons for 2030 (USACE-3-7 inches) and 2060 (USACE- 9-24 inches).
c. A science-based narrative for 2060 and beyond provides context for the current state of the science and potential issues to consider in the long term.
d. The unified projection will need to be reviewed and potentially revised within a two year timeframe especially following the revision of the USACE Sea Level Rise Guidance document in June 2011
e. Users of the projection should keep in mind that at any point of time, sea level rise is a continuing trend and not an endpoint.

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