Estimating Economic Benefits from NOAA PORTS® Information: A Case Study of Tampa Bay

July 2005

TAMPA BAY
HARBOR SAFETY & SECURITY COMMITTEE

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Report prepared for the Tampa Bay Harbor Safety Committee by Dr. Hauke Kite-Powell of the Woods Hole Oceanographic Institute Marine Policy Center. Funding for the report was provided by the National Oceanic and Atmospheric Administration (NOAA). The report utilizes a PORTS® economic assessment methodology developed by Dr. Kite-Powell for NOAA and published under separate cover as a tool to estimate the economic benefits provided by an existing or proposed PORTS®.

Hauke Kite-Powell

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Summary

This report estimates the economic benefits derived from the Physical Oceanographic Real-Time System® (PORTS®) installation at Tampa Bay. We estimate benefits in dollar terms to the extent possible, and also describe non-quantifiable benefits.

Sources of economic benefit from Tampa Bay PORTS® information include:

- Greater draft allowance/increased cargo capacity and reduced transit delays for commercial maritime transportation (water level information)
- Reduced risk of groundings/allisions for maritime traffic (currents and wind information)
- Enhanced recreational use of Tampa Bay by boaters, windsurfers, etc. (winds, weather forecasts, and other information)
- Improved environmental/ecological planning and analysis, including hazardous material spill response

In Table 1 on the following page, we summarize estimates of the annual economic benefit to a range of activities. We divide these estimates into three categories: those estimates for which there is direct evidence and in which we can have a high degree of confidence; those that are likely to be realized at present but for which direct evidence is lacking and/or significant assumptions are required; and those that are more speculative or potential, and could be realized with the full utilization of Tampa Bay PORTS® data by all potential users.

Our estimates suggest that $2.4 to $4.8 million in direct annual economic benefits can be attributed to PORTS® data in the Tampa Bay area with a reasonable degree of confidence. Another $2.2 million in annual benefits are less easily traced but may be linked to PORTS; and an additional $2.2 million could potentially be realized with the full utilization of PORTS® data. Thus, our best estimate of the presently realized quantifiable benefit from Tampa Bay PORTS® data is $4.4 to $7.0 million. This estimate is best interpreted as a lower bound on total benefits flowing from PORTS® data, since not all uses of PORTS® data can be quantified.

Most of these benefits are in the nature of avoided costs (increased producer surplus, or profit) for commercial operations and avoided costs or increased consumer surplus, including non-market benefits, for recreational users of the Bay.

Table 1: Summary of Estimated Annual Benefits from Tampa Bay PORTS®

confidence level	***Source of benefit***	***Nature of benefit***	***approx. annual value (2005 $)***
High confidence reasonably good confidence and/or direct evidence for benefits	avoided groundings, commercial vessels	avoided costs (surplus)	1,100,000 – 2,800,000
	increased draft, cargo loading	efficiency (surplus)	1,100,000
	reduced delays, commercial vessels	avoided costs (surplus)	10,000
	improved spill response (present practice)	avoided costs (surplus)	200,000 – 900,000
Subtotal – high confidence benefits			**$2.4 – 4.8 million**
Lower confidence more significant assumptions required to estimate benefits; less direct evidence	reduced distress cases, recreational boats	avoided costs (surplus, value of life)	200,000
	improved weather forecasts	non-market consumer surplus	1,500,000
	improved storm surge forecasts	avoided costs (surplus)	500,000
Subtotal – lower confidence benefits			**$2.2 million**
Potential or speculative these benefits could be realized with additional investment or a higher level of utilization of PORTS® data	improved spill response (with add'l models & infrastructure)	avoided costs (potential; not realized at present)	900,000
	enhanced recreational boating	non-market consumer surplus	1,000,000
	enhanced recreational fishing	non-market consumer surplus (potential; not realized at present)	100,000
	enhanced beach recreation	non-market consumer surplus	200,000
Subtotal – potential or speculative benefits			**$2.2 million**
Non-quantified benefits	Educational use	non-market	N/A
	Scientific research	non-market	N/A

INTRODUCTION

NOAA Physical Oceanographic Real-Time Systems® (PORTS®) are near-shore ocean observing systems now operating in a dozen locations around the United States (http://co-ops.nos.noaa.gov/d_ports.html). PORTS® installations provide near-real time information and, in some cases, forecasts about water levels and currents at specific points in a coastal water body. In some instances, they also provide information on wind speed and direction, and on water temperature. In addition, co-located sensors (i.e., possibly operated by other parties and not part of the official NOAA PORTS® installation) may provide information on wave height, visibility, air gaps an bridges, and other parameters, as well as digital still or video images of portions of the waterbody.

The information made available by PORTS® results in economic benefits because it is used by decision makers to make choices that affect economic well-being. To estimate the benefits that may accrue from a PORTS® installation, it is necessary to compare the outcome of these choices under two scenarios: the PORTS® scenario, in which the PORTS® data are available to decision makers; and a non-PORTS® scenario, in which these data are not available. The data and products enabled or affected by the PORTS® installation influence decisions made in industry, recreation, the research community, and public administration, changing the economic outcome from these activities, and thereby affecting economic well-being. The difference in outcome under the two scenarios is the benefit derived from the investment in PORTS®.

The most accurate measure of this benefit is the marginal increase in what economists call consumer and producer surplus. Consumer surplus is the difference between what consumers are willing to pay and what they actually pay. Producer surplus is the difference between the price received for a good or service sold and the costs of producing that good or service. Because this surplus is often difficult to estimate, economists also use other measures of benefit, such as the change in value added (contribution to GDP), or reduction in cost to achieve the same level of output. These measures typically are less precise estimates of true social surplus. Usually, these measures are estimated as annual values at the level of a firm or other economic unit, and then aggregated over geographic regions and industries to estimate total annual benefits.

Benefits represent only one side of the investment decision. To estimate net benefits, or rates of return, it is necessary to have information on costs as well. In the case of PORTS®, there are two main categories of costs: the cost of data collection, processing, and archiving; and the cost of generating from these data the products that decision makers ultimately use. In the case of PORTS®, the first component (the direct capital and operating cost of the PORTS® installation) is usually well understood. The second component generally includes activities carried out by both public and private sector organizations, and these costs are likely to be more difficult to specify. The analysis of costs associated with the generation and use of PORTS® data is outside the scope of this report.

ECONOMICS OF INFORMATION

A product, such as a real-time water level report for a harbor, represents information about the ocean environment. This information has value when it can be used by an individual or an organization to make a better decision – that is, a decision that results in an outcome that is economically superior. The standard economic approach to valuing information requires:

- A description of the information being valued and of the state of knowledge about the phenomena or conditions it describes. Typically, information is useful because it reduces uncertainty about the present or future state of nature in a particular context – for example, the location of a particular depth contour, or the exact water level in a dredged channel.

- A model of how this information is used to make decisions. Most decisions are made in the face of imperfect information, or uncertainty about how conditions will in fact develop and what the exact outcome will be. For example, PORTS® data may be used in decisions involving the navigation of commercial or recreational vessels. Here, the critical information concerns water depth, current speed and direction, wind speed and direction, or other information needed for the safe and efficient operation of a vessel.

- A model of how these decisions affect physical outcomes. Modeling the difference in outcome with and without the product in question usually requires making assumptions about how the decision makers will respond to the lack of the product in question.

- A model of how physical outcomes can be translated into economic outcomes. The value of a product is the difference between the expected value of the outcome of decisions using that product, and the expected value of the outcome without the product.

Quantifying Economic Value

The most appropriate measure of economic value of information resulting from a change in user decisions or behavior is the change in what economists refer to as "social surplus." Social surplus has two components: producer surplus and consumer surplus. Producer surplus in this case is generally a reduction in costs to businesses. Consumer surplus, as in the case of the surfer, is the difference between what one would be willing to pay and what one actually pays for, for example, a recreational experience. "Social surplus" is the sum of producer and consumer surplus. It is the appropriate measurement because it assures that only the value in excess of costs is counted, making it a unique measure that avoid the artificial inflation of values by double counting.

The problem with social surplus and both of its elements is that they can only be measured using exacting, time-consuming, and costly techniques. Other measures of economic activity (broadly termed "economic impacts") such as the value of sales at the wholesale or retail level, or value added (the most common example of which is the Gross Domestic Product, or GDP), are widely available, but measure social surplus in a rather imperfect manner.

In other situations, estimates of social surplus may be available but data to support an explicit model of how PORTS® information is used in economic decisions are lacking. In such cases, an order-of-magnitude estimate of potential value of PORTS® data may be obtained by applying a rule of thumb developed by Nordhaus (1996) and others: the value of weather and climate forecasts to economic activities that are sensitive to weather/climate tends to be on the order of one percent of the economic activity in question.

Studies of economic values from investments such as PORTS® thus often face a dilemma due to data constraints. The most appropriate measure is the least available, while the most available measures are the least appropriate. This is a major reason why these estimates of economic benefits often must be considered approximate.

SOURCES OF ECONOMIC BENEFIT FROM PORTS®

PORTS® data, and products derived from PORTS® data, are used by a wide range of industrial, recreational, and public sector organizations and individuals. They include maritime shipping interests, recreational boaters and fishers, and marine resource and environmental managers.

For the purpose of this analysis, we use the following classification of benefits from PORTS® installations:

- Improved Safety of Shipping and Boating
  - Avoided groundings, commercial vessels
  - Avoided distress cases, recreational vessels

- Improved Efficiency of Marine Operations
  - Increased cargo carried per ship call (greater loaded draft)
  - Reduced delays (less allowance for error/margin in piloting decisions)
  - Improved SAR performance (surface currents)

- Improved Environmental Protection and Planning
  - Improved hazardous material spill response
  - Improved environmental restoration/conservation activities

- Improved Recreational Experiences
  - Enhanced value from boating decisions (power, sail, windsurfing, kayaking, etc.)
  - Enhanced value from fishing decisions
  - Enhanced value from beach visit decisions

- Improved Weather and Coastal Marine Conditions Products
  - Improved general weather forecasts
  - Improved coastal marine weather forecasts
  - Improved storm surge forecasts

- Science and Education
  - Use of PORTS® data in scientific research
  - Use of PORTS® data in secondary education

While this list is not exhaustive, it captures to the best of our knowledge all of the major benefits generated by PORTS® data.

In each of the benefit categories discussed above, it is possible to estimate the potential value of PORTS® data by assuming that all potential users of the information in fact make use of it as described. This potential value is an upper bound of sorts on what is likely to be the value actually realized during a given year, since the number of actual users is likely to be less than 100% of potential users, 100% of the time. Potential value is often easier to estimate than actual value because estimating potential value does not require data on how many users actually use the PORTS® data, and how often.

In situations where data or model limitations do not permit the application of the benefit frameworks described above, it may be possible to estimate at least the general scale of potential benefit by applying a "one percent proxy rule." Formulated by Nordhaus (1986) and other economists on the basis of experience with a number of forecast/nowcast value of information studies of industries and activities sensitive to weather, this rule suggest that the value of weather nowcast/forecast information to economic activity sensitive to weather conditions is generally on the order of one percent of the economic value generated by the economic activity. There is, of course, no guarantee that this rule will hold in all cases; but where no better estimate can be constructed, it provides an order of magnitude estimate of value that is likely to be reasonable.

ECONOMIC BENEFITS FROM TAMPA BAY PORTS®

Background: Tampa Bay PORTS®

The Tampa Bay Physical Oceanographic Real-Time System® (PORTS®) is a public information acquisition and dissemination technology developed by the National Ocean Service (NOS) in cooperation with the Greater Tampa Bay Marine Advisory Council. It was deployed in Tampa Bay in 1990-91, and is managed, operated, and maintained by the Greater Tampa Bay Marine Advisory Council-PORTS® under a cooperative agreement with NOS and the University of South Florida.[1]

Tampa Bay PORTS® provides information in near-real-time on currents, water levels, winds, air and water temperatures, and barometric pressure at multiple locations with a data dissemination system that includes telephone voice response, modem dial-up, dedicated modem displays, and World Wide Web/Internet sites (http://co-ops.nos.noaa.gov/tbports/tbports.html; 1-866-827-6787 (1-866-TBPORTS)). Tampa Bay PORTS® infrastructure includes four acoustic Doppler current profilers (ADCPs), four water level gages, six anemometers (wind sensors), an atmospheric temperature and barometric pressure sensor, packet radio transmission equipment, a data acquisition system, and an information dissemination system. Data are taken at six-minute intervals at eight locations in Tampa Bay, as follows in Table 2. Data on wave height and direction (a directional wave gauge), and visibility, as well as web cameras providing visual images of portions of Tampa Bay, are co-located with certain PORTS® sensors and operated by other parties, such as the University of South Florida (http://ompl.marine.usf.edu/PORTS/PORTS.brochure.html).

	water level	current	wind	wave height/ direction*	visibility*
Old Port Tampa	X	X	X		
Port Manatee	X		X		
Manatee Channel Entrance		X	X		
Port of Tampa	X				
St. Petersburg	X		X		
Sunshine Skyway		X	X		X
Egmont Channel		X	X	X	X

Table 2

*wave and visibility parameters are not part of the NOAA PORTS® installation and are operated by other parties

[1] Information in this section is based on the description of Tampa Bay PORTS® on the system web sites, http://co-ops.nos.noaa.gov/tbports/tbports.html, http://ompl.marine.usf.edu/PORTS/, and related web pages.

General Notes on Value of Tampa Bay PORTS®

To maximize the value generated by data from PORTS®, it is necessary to ensure that the information reaches all potential users in a timely manner and user-friendly format. A single, common, graphic, web-based interface for data is particularly well suited for the widely dispersed recreational user community. It is also important to leverage the actual observations, which of necessity will be limited to a relatively small number of geographic locations, through the use of models that interpolate between and extrapolate or forecast from these observations to provide more complete geographic and temporal coverage. The NOAA PORTS® web pages for Tampa Bay (http://co-ops.nos.noaa.gov/tbports/tbpicsgif.html) provide a view of what is presently available; projects such as the Tampa Bay Interactive Mapping System (part of the USGS Integrated Science Project, http://gulfsci.usgs.gov/tbay_ims/index.html) plan in the future to present an integrated view of circulation model output and other data.

There is little hard data on the utilization of PORTS® data by specific user categories. Apart from some general statistics on the number of "hits" on the Tampa PORTS® web page, no survey has been undertaken to determine how many users from each user group utilize Tampa Bay PORTS® information, how often they do so, and how they utilize the information. Anecdotal data gathered in the course of research for this report suggests that PORTS® data are used extensively by the maritime operations and safety communities, but utilization and even awareness among recreational users is quite low. This leads to our classification (see Executive Summary) of many recreational benefit estimates as more speculative or potential. To achieve a higher degree of confidence in these estimates, it will be necessary to carry out specific surveys of these users.

Safety

Avoided Groundings, Commercial Vessels

PORTS® data have been available to maritime operations in Tampa Bay since the early 1990s, and since the late 1990s, Tampa Bay pilots have carried laptop computers with electronic chart software, GPS, and wireless PORTS® link onto the ships they guide through the Bay. Although they do not prove causality, historical data on grounding rates for commercial transits of Tampa Bay suggest a reduction in grounding risk accompanied the introduction of PORTS® in the early 1990s.

Data on commercial vessels grounding are drawn from the USCG's accident databases known as CASMAIN (1981-90) and MSIS (1992-95). Data for 1991 are sparse and evidently incomplete in each dataset; here, we have replaced the 1991 counts by averages of the surrounding years for purposes of analysis. From the USCG data we selected for inclusion in this study only accidental, navigational groundings, and ignored those identified as intentional or due to mechanical failure or other, clearly non-navigational cause.

Transit data are based on ACE Waterborne Commerce Statistics annual summaries, 1981-1995 (see USACE, various years). For our purposes, a "transit" is a vessel movement, so that a port call usually consists of two transits: one into and one out of the port. To avoid double counting, we based our transit count on data for only one "waterway" as defined by USACE; in this case: waterways code 2021 (Tampa Harbor). Average annual transit counts during 1981-95 were 3,700 self-propelled ships and about 3,000 barge trains. For 2003, the USACE reports about 4,300 self-propelled ship transits and 2,500 barge train movements.

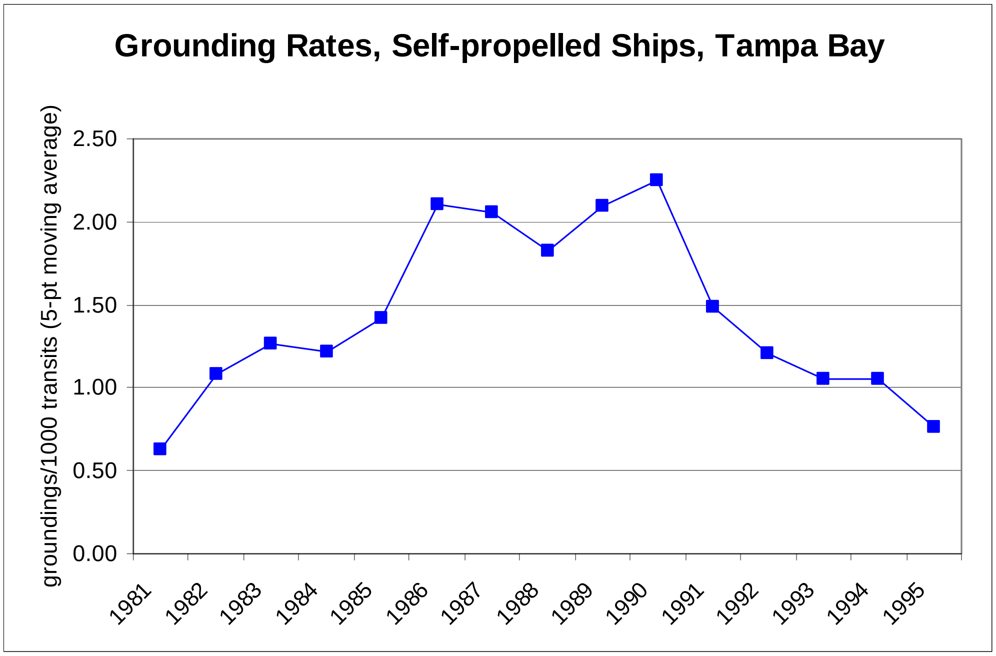

Figure 1

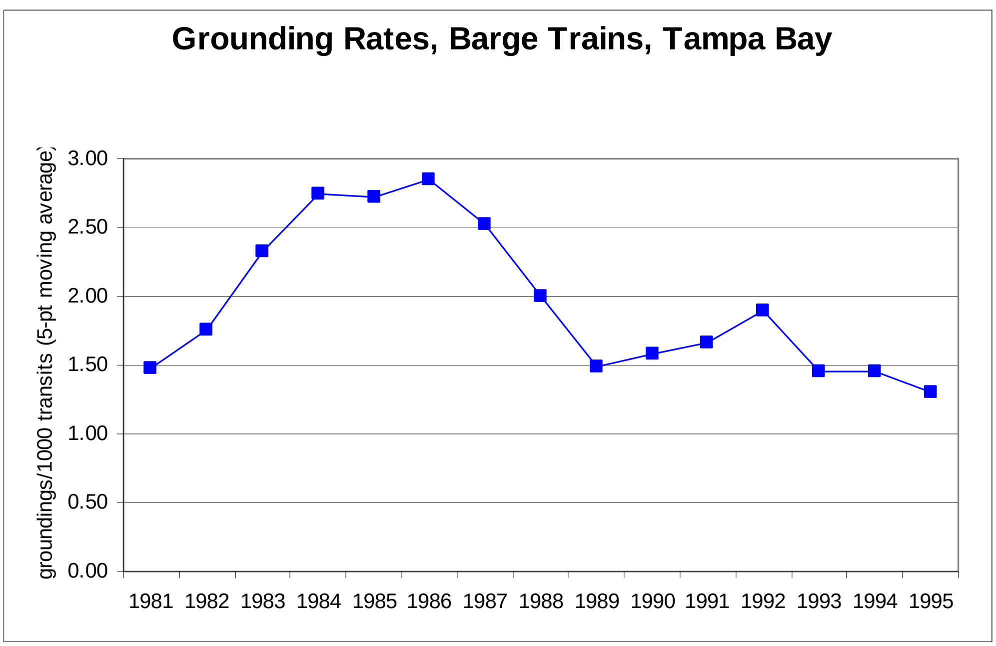

Figure 2

Figures 1 and 2 show resulting time series of grounding rates in Tampa Bay for self-propelled ships and barge trains, respectively. Our focus here is on the self-propelled vessels, most of which are piloted and likely to have made use of PORTS® data. The data show a distinct decline in grounding rates in the early 1990s, during the time when PORTS® data first became available. This correlation does not establish causality; other factors may well have contributed to this apparent decline in grounding risk. However, it is plausible that the availability of PORTS® data materially contributed to this development.

The availability of PORTS® data was perhaps the most significant change in the maritime operating environment of Tampa Bay during the early 1990s (M. Farley, p.c. 2005); a related significant change came with the introduction of PORTS®-linked portable computers used by pilots onboard vessels in the Bay as of 1998. Tampa Bay maritime safety officials confirm that grounding risk has remained around 0.5 groundings per 1,000 deep-draft transit since these measures were introduced (M. Farley, p.c. 2005). Given this these developments, a plausible range for the decrease in grounding risk for Tampa Bay self-propelled ship transits attributable to PORTS® data is from 20 to 50% from the long-term baseline level of about 1.5 grounding per 1,000 transits. This implies that PORTS® data prevent between 1.3 and 3.2 deep-draft groundings per year in Tampa Bay.

The economic loss associated with a grounding is the sum of all costs associated with the accident. Costs are classified as either internal or external. Internal costs are those arising from the vessel involved in the accident and other parts of the marine transportation system; they include damage to the vessel, loss of cargo, injury or death of crew members, cleanup costs, and delays due to blockage of the route, among others. External costs are those incurred outside the transportation system, including environmental degradation, human health risks, lost fishery revenues, and lost recreational benefits, among others. Both external and internal costs will vary with the severity of the accident; the size of the vessel(s) involved, their construction, and their cargo; and other factors. External costs will also vary greatly with the environmental and human health sensitivity of the location.

We use here an estimate of the cost of groundings that is based on the approach taken in the Coast Guard's *Port Needs Study* (PNS) (USCG 1991), taking into account relevant parameters such as vessel size, nature of cargo, and nature of the transit area. The PNS study included in its loss estimation each of the following categories of losses (see Schwenk 1991):

- loss of human life and personal injuries,
- vessel hull damage,
- cargo loss and damage,
- economic cost of the vessel being out of service,
- spill clean up costs,
- losses in tourism and recreation,
- losses in commercial fish species,

- impacts on marine birds and mammals,
- losses due to LPG/LNG fires and explosions, and
- bridge and navigational aids damage.

Not included in the estimation procedure are damages to on-shore facilities and water supplies, legal fees for litigation over vessel casualties, cumulative effects of consecutive spills, effects of chemical releases into the air, and non-use values.

A summary of the PNS loss estimation procedure is provided by Schwenk (1991). In addition to its own procedures, PNS draws on several sources for damage estimation models. These include the Natural Resource Damage Assessment Model (see below); several models developed by A.T. Kearney (1990) for losses in tourism, property values, and subsistence households; and models by ERG (1990) for losses due to cleanup costs and to vessel damage and repair. The PNS data, which reflect inputs from all of these models, are used to estimate the losses associated with one accident involving various vessel types (tanker, dry cargo, tug/barge) and sizes in each study area.

Perhaps the most volatile element in the PNS loss estimation procedure is the model used to calculate natural resource damages. These damages -- loss of fish, birds, marine plants, and other species -- account for between 10 and 40 percent of total damages, depending on the location and nature of the accident. The PNS results are based on a version of the Department of the Interior's Natural Resource Damage Assessment Model for Coastal and Marine Environments (NRDAM/CME) which has since been replaced by a new version of NRDAM/CME (see Federal Register 59(5):1062-1189). The new version includes a new model of restoration costs and makes use of updated biological, chemical, and economic data. Preliminary analysis of the new model's parameters suggests that there is no consistent way to scale results from the previous version to reflect the likely new model results. The cost estimation algorithm we have used here therefore includes natural resource damage estimates based on an "old" version of the NRDAM/CME.

Based on the PNS data, the average economic loss associated with self-propelled ship grounding in Tampa Bay is $1.25 million for tankers and $0.5 million for dry cargo vessels (in current 2005 dollars). These averages take into account the distribution of vessel size and cargo for each port, and also reflect seasonal averages for environmental losses. They also reflect the relatively “forgiving” nature of the seabed in Tampa Bay, which does not have the hard rock bottom of other US harbors. Fortunately, most Tampa Bay groundings to not result in major damage to vessels or in spills of fuel or cargo. In fact, there has not been a significant grounding-related spill in Tampa Bay in many years.

Tankers account for 2,200 Tampa Bay transits per year, or roughly half of the self-propelled total. Using the assumptions described above, the 20-50% reduction in grounding risk due to PORTS® translates into a conservative estimate of $1.1 million to $2.8 million in avoided costs per year.

Anecdotal evidence supports the claim that PORTS® data help prevent groundings in Tampa Bay. For example, the entrance to Port Manatee Channel requires a sharp turn across the flow of the tide, and must be negotiated at slack tide by many vessels. A 1996 tanker grounding at this location has been attributed in part to reliance on tide tables only to estimate slack water time during that transit; PORTS® data are now routinely used for this purpose.

Reduced distress cases, recreational vessels

The USCG (2004) reports 752 significant recreational boating accidents in Florida waters during 2003, leading to 64 fatalities, 487 injuries, and $9.7 million in property damage. Nationally, hazardous water and weather are a causal factor in about 10% of recreational boating accidents (data specific to Florida waters have not been identified).

Of the 940,000 boats registered in Florida in 2003 (USCG 2004), about 110,000 are registered in Manatee, Hillsborough, and Pinellas Counties (Sidman *et al.* 2004). If we assume that recreational boating activity and accident rates in the Tampa Bay area are similar to those in other parts of Florida, this suggests about seven significant weather-related accidents per year in Tampa Bay, with 0.5 fatalities, 5 injuries, and $100,000 in property damage.

PORTS® data can play a significant role in improving recreational boaters' weather awareness and preventing weather-related accidents. For example, web cameras integrated with PORTS® stations can allow boaters to see conditions "first-hand" before they set out; and this probably leads to reduced incidence of distress situations, according to Coast Guard officials in Tampa (p.c. 2004). Boaters encounter about 30 days of zero visibility conditions on the Bay in an average year.

If we assume a value of life of $4 million, the direct cost associated with weather-related recreational boating accidents on Tampa Bay is on the order of $2 million/year. All of these could potentially be avoided by scrupulous use of PORTS® and other weather information. Observers knowledgeable about the Tampa Bay recreational boating community suggest that between 10 and 50 percent of boaters are aware of, and make use of PORTS® data today. A conservative estimate of benefits from PORTS® in this instance may be 10% of expected losses, or $200,000/year.

Efficiency

Increased cargo carried per transit

The major cargos transshipped through Tampa Bay are petroleum imports and phosphate exports.   Petroleum products arrive from Gulf Coast refineries and from the Hess facility on St. Croix in the Caribbean. About 60 percent of petroleum coming into Tampa moves in barges, which are generally not draft constrained. Tank ships (product tankers) calling on Tampa generally have a fully loaded draft of 35.5 ft; this is also the controlling depth in the Sparkman Channel, which leads to many of the port's fuel depots. (This channel cannot be deepend further because of constraints imposed by the City of Tampa sewage pipe.) Nominal depth at many of the fuel docks is 33.5 ft, but a strong NE wind can push water levels at the docks down to 30 ft.

Phosphate exports are carried from Tampa in self-propelled dry bulk freighters. Most of this cargo is bound for destinations in Asia and Australia via the Panama Canal, and under present Panama Canal operating rules faces a typical draft limit for Canal transits of 39.5 ft. The controlling depth in the main Tampa Bay channels is 39 to 40 ft. Phosphate shipments thus face Tampa Bay draft constraints primarily at the docks. Pre-PORTS® underkeel clearance requirements for Tampa Bay called for 2 ft of clearance; with PORTS, pilots now move ships with 6 inches of clearance (USCG, p.c. 2004).

This suggests that PORTS® data may provide the ability to load some ships to drafts 12 inches or more above what used to be considered safe prior to PORTS®. The number of dry cargo transits out of Tampa Bay with draft of 38 ft or more in 2003 was about 50 (USACE). Using the assumptions summarized in the Table 3 below, and the approach outlined earlier in this report, we estimate the annual potential benefit to phosphate trade from PORTS® data (AV) as about $1.1 million.

$$AV = (AD \times TPI \times NC / AC) \times ((RT \times SC / KTS) + (DOC + (2AC / LR)) \times PC)$$

Parameter	***Variable***	***Value***
Additional draft enabled by PORTS® information (inches)	AD	12
Tons per inch immersion	TPI	90
Average cargo per transit without PORTS® (tons)	AC	60,000
Number of transits/year affected by PORTS® data	NC	100
Average round-trip distance (nm)	RT	15,000
Operating cost at sea (incl. fuel) ($/hr)	SC	600
Vessel speed (kts)	KTS	15
Docking and undocking time per transit (hours)	DOC	24
Loading/unloading rate (tons/hr)	LR	1,200
Operating cost in port ($/hr)	PC	200

Table 3

Reduced delays

A Tampa Bay traffic protocol governing the movement of certain "vessels of concern," in place since 1995, requires one-way traffic in the Bay when vessels of concern are transiting. Cruise ships are included in this category because of their large beam and the limited channel width in Tampa Bay; and ammonia carriers are included because of the hazardous nature of their cargo. The potential delays associated with these one-way restrictions are well understood by users of the Bay and generally built into their operating schedules now. Under the *Vessel of Concern Traffic Protocol* issued by the Captain of the Port, vessels of concern must enter Tampa Bay between 0200 and 0400, with docking between 0530 and 0730; the departure window runs from 1600 to 1730.

Other Tampa Bay operating constraints have been relaxed due to the availability of PORTS® data and the resulting increase in confidence among pilots about conditions they will face during transits. Tampa Bay Pilots used to hold draft-constrained ships until maximum high tide, or delay vessels until winds died down. Port Manatee traffic was restricted to daylight operations only prior to PORTS®. The pre-PORTS® underkeel clearance requirement in Tampa Bay was 2 ft, and has since been reduced to 6 inches. All of these developments reduce the likelihood and severity of transit delays.

Hard data on delays are not available for Tampa Bay. If we assume, conservatively, that PORTS® data reduces delays in one percent of transits (67 transits/year) by 60 minutes, and an average operating cost of $200/hr, this translate to $13,400/year in operating cost savings.

Improved SAR performance

According to search and rescue officials, PORTS® data are not a significant factor in improving SAR performance within Tampa Bay (Farley, p.c. 2004).

Environmental Protection: improved spill response

There has not been a major vessel-related spill in Tampa Bay since 1993. The 1993 spill involved a collision between a phosphate freighter and two fuel barges; some 330,000 gallons were spilled. Wind and tide moved most of the spill out to sea, but much of it eventually returned to St. Petersburg beaches. PORTS®-related data predicted the spill's trajectory well but played no significant role in spill response efforts. The combination of relatively soft seabed, one-way traffic rules, and PORTS® data make for a relatively low spill risk in Tampa Bay.

Facility spills, usually associated with tropical storm events (e.g., 2004 phosphoric acid spill in Hillsborough Bay), are at least as much of a concern in Tampa Bay as vessel spills. No significant response measures exist to mitigate the effects of phosphate process water (phosphoric acid) or ammonia spills. However, models incorporating PORTS® data can provide information on concentrations of acids and other contaminants after a spill event, and together with biological data are used to estimate mortality in biological communities in the Bay, for use in damage assessment. Although much of the Bay is regularly flushed by tides, residence time of water in the Bay varies, and can be as long as two weeks in upper bays.

Damage assessment model exercise conducted by Knutsen (p.c. 2005) considered a hypothetical spill of 328,000 gallons of #6 fuel oil from a vessel near the Skyway Bridge on an incoming tide (scenario similar to the 1993 spill, but on a different part of the tide cycle). The Florida State formula natural resource damage assessment model estimated resulting environmental damages of $460 million. It is not known precisely how the availability of PORTS® data would influence spill response efforts in the event of such a spill, or how that change in response would affect (reduce) environmental damages. If we assume, conservatively, a 1% to 5% reduction in damages due to the use of PORTS® data in spill response activities, and that such spills will happen in Tampa Bay once every 25 years, the expected annual benefit is between about $180,000 and $900,000.

According to spill response officials, present technology and practice typically allows for the recovery of about 10 percent of spilled oil (Watabayashi, p.c. 2005). Some oil spill modelers suggest that greater improvements in cleanup effectiveness will be possible once PORTS®-like data are integrated directly with more sophisticated hydrodynamic current models and models of hydrocarbon transport and fate. Such models exist today and are used in risk assessment exercises, among others for spill events in Tampa Bay (see French *et al.* 1999, French McCay *et al.* 1999, also Mark Luther's work at the Ocean Modeling and Prediction Laboratory at USF, http://ompl.marine.usf.edu/). These models are not at present used directly in guiding "live" spill response activities. If these models are combined with appropriate spill response, modelers suggest that it may be possible to increase recovery to 20% and target recovery efforts more effectively to minimize environmental damage (French McCay p.c. 2005). If this can be achieved, environmental damages may be reduced by an additional 5% or so. In Tampa Bay's case, using the above assumptions, that means another $900,000/year in expected avoided losses.

Enhanced Value of Recreation Activities

It is estimated that between 10 and 50 percent of the recreational boating community around Tampa Bay is aware of and (at least occasionally) making use of PORTS® (Sherburne, p.c. 2004). About 9% of boaters surveyed in 2003-2004 indicated that they would like to have more or better information about weather (tide, wind, lightning, seas); and one third of these mentioned the internet as the preferred medium for obtaining this information (Sidman *et al*. 2004).

Boating

About 110,000 recreational boats are registered in Manatee, Hillsborough, and Pinellas Counties as of 2004 (Sidman *et al*. 2004). The typical boater makes about 3.5 trips per month, averaged over the year – or 43 trips/year. Most are day trips, although there are also a substantial number of overnights. About 91 percent of boaters surveyed in 2003 and 2004 had internet access.

Assuming that a boating day generates economic surplus equal to about 10 percent of actual expenditures (Hushak 1999), we estimate the per day surplus from recreational boating at $20/day. If PORTS® data leads to a one percent increase in positive boating day experiences in Tampa Bay, this suggests in annual non-market benefit from PORTS® of $946,000.

Fishing

64% of recreational boaters surveyed in Tampa Bay 2003-2004 engaged in fishing (Sidman *et al.* 2004). Recreational fishers and guides/charter operators are interested in water temperature and in details of current speed and direction (fish are usually not caught during slack water). Estimates of willingness to pay for increased fishing success on Florida's Gulf coast range from $3 to $23 per fishing trip (Haab *et al.* 2000).

Using a value of $10 per fishing trip, and assuming that boaters who fish do so on 50% of their boating trips, and that PORTS® data leads to improved fishing success on one percent of fishing trips, we estimate the value of PORTS® data to fishers in Tampa Bay at about $150,000/year. We consider this a potential benefit because it is not known how many recreational fishers routinely utilize PORTS® data at this time.

Beach Visits

Surveys indicate that some 15 million beach visitors spent 177 million beach days in Florida in 2000 (Leeworthy and Wiley 2001). Typical expenditures directly associated with beach recreation are $25 per beach day, and generate an estimated $15 of consumer surplus per beach day (Pendleton 2003). Assuming that one percent of Florida beach days take place on beaches around Tampa Bay, and that PORTS® can lead to a one percent improvement in economic surplus generated by beach use, this suggest an annual benefit of $265,000. We consider this to be a potential benefit because there is no solid evidence that beach visitors regularly make use of PORTS® data at this time.

Enhanced Weather Forecasts

General Weather and Coastal Marine Forecasts

PORTS® data are used in the local analysis and prediction system operated by the National Weather Service office in Tampa. As such, these data help improve both general weather forecasts for the Tampa Bay area and coastal marine weather forecasts. The value of improved coastal marine forecasts is reflected in the improved recreational boating experience of local boaters, as discussed above. The improved general weather forecasts benefit all users of weather forecasts in the Tampa area.

Data used include water level information (for coastal flooding), wind speed and direction, and temperature. The weather service uses PORTS® data to verify marine warnings generally, and as a basis for marine warnings issued for Tampa Bay. The Weather Service typically issues about 20 severe weather warnings/year, mostly during the summer, as well as several coastal flood warnings (see below). Some of these warnings are based directly on PORTS® data (C. Paxton, NOAA NWS, p.c. 2004).

The exact contribution of PORTS® data to improved weather forecasts for the Tampa Bay area is not known. Using Lazo and Chestnut's (2002) estimate of about $15/household/year for the value of significant improvements to general weather forecasts, assuming that PORTS® data contribute 10 percent of such an improvement, for an estimated 1 million affected households, results in an annual benefit from improved weather forecasting of $1.5 million. We consider this a lower confidence estimate because although the mechanism is clear and the use of PORTS® data in this context is well established, the magnitude of the contribution of PORTS® to the weather forecast is difficult to quantify.

Storm Surge Forecasts

Storm surges are associated with large storm events, such as hurricanes, and can cause extensive damage. Much of this damage cannot be avoided by an improved forecast, but marginal improvements in response activities (securing boats and structures, evacuating areas) may be possible or less costly with a more accurate and timely forecast.

The Tampa Bay area is considered among the most endangered in the country from storm surge because of its large population and because the geography of the Bay and surrounding areas can "trap" the storm surge and cause it to build up significantly. Storm surges that measure a few feet in height at sea can build to more than 15 feet in confined shallow water and nearshore areas. Nearshore areas along tidal bays and rivers are particularly vulnerable. A large storm surge can submerge much of downtown Tampa.

Major storm surge events hitting urban areas can cause billions of dollars in damages. Assuming a $1 billion storm surge damage from a major storm once every 20 years in the Tampa Bay area, we estimate an annualized risk from storm surge of $50 million. The precise contribution of PORTS® data to storm surge forecast quality and risk reduction is not known. Applying the one percent rule, we estimate an annualized value of $500,000 from improved storm surge prediction.

Qualitative Effects and Values

PORTS® data are used in educational and scientific activities that are valuable but do not lend themselves to economic quantification. Examples of these are highlighted below. Although we do not attempt to quantify benefits from these activities, they are important uses of PORTS® data and suggest that the quantified benefits should be treated as a lower bound estimate of total benefits from PORTS®.

Educational use of PORTS®

PORTS® data are used Pinellas Country's Environmental Distance Learning project (http://www.edlonline.org/). This internet-based system makes use of PORTS® data in a variety of learning projects for primary school students. It is used by some 2,500 teachers and recorded 1.3 million internet hits in 2003, 70 percent of which came from within Florida (P. Luther, p.c. 2004).

Scientific Research/Water quality management

A Comprehensive Conservation and Management Plan for Tampa Bay (EPA National Estuaries Program) was adopted 1996. This plan addresses water and sediments, habitats, dredge material disposal, spill prevention and response, and public education and access. PORTS® data are used in scientific research that supports work associated with this plan and with other water quality initiatives in Tampa Bay. Research activities include the development and application of circulation models for Tampa Bay to study nutrient level effects associated with phosphate process water spills, atmospheric deposition of nitrogen via volatilized ammonia, desalination plants, and diversion of fresh water from rivers leading into Tampa Bay.

One of EPA's environmental goals is to restore sea grass in Tampa Bay to 1950s levels. This requires improved water clarity, which in turn requires a reduction in nitrogen (nutrient) levels. Atmospheric deposition historically accounts for 50 percent of nitrogen input (as well as mercury and other substances) to the Bay. Atmospheric flux models used to develop policies to address this issue are driven by wind speed and direction data, provided in part by PORTS®.

Harmful algal blooms occur in late summer in Tampa Bay, driven by water temperature and nutrient loads. These blooms can lead to shellfish area closures, beach closures, and sometimes restrictions on boating activity. PORTS® data can play a role in predicting these blooms and in minimizing their adverse effects.

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I was struck throughout my time in Tampa with the pleasantly collegial and collaborative atmosphere within the Tampa Bay marine community.

BIBLIOGRAPHY

A.T. Kearney. 1990. Methodology for estimating the environmental costs of OCS oil and gas exploration, development, production, and transportation. Kearney Centaur Division. Washington: A.T. Kearney.

Allen, A. 2004. CODAR for Coast Guard applications: business case. USCG R&D Center, Groton, CT.

Amrozowicz, M.D. 1996. The quantitative risk of oil tanker groundings. Master's degree thesis, Ocean Engineering Department, Massachusetts Institute of Technology, Cambridge, Massachusetts.

Berger, J.O. 1985. *Statistical decision theory and Bayesian analysis*. New York, Springer Verlag.

Eastern Research Group (ERG), Inc. 1990. Estimates of costs associated with oil and hazardous chemical spills and costs of idle resources during vessel repairs. Prepared for the John A. Volpe National Transportation Systems Center as part of the Port Needs Study (see USCG 1991).

French, D.P., H.Z. Schuttenberg, and T. Isaji. 1999. Probabilities of oil exceeding thresholds of concern: examples from an evaluation for Florida Power and Light. Pages 243-270 in Proceedings of the AMOP 99 Technical Seminar, June 2-4 1999, Calgary, Alberta, Canada.

French McCay, D.P., M.A. Jones, and L. Coakley. 1999. Oil spill modeling for contingency planning and impact assessment and example application for Florida Power and Light. Applied Science Associated, Narragansett, Rhode Island.

Haab, T., J. Whitehead, and T. McConnell. 2000. The economic value of marine recreational fishing in the Southeast United States. 1997 Southeast Economic Data Analysis Final Report.

Hushak, L. 1999. Recreational boating in Ohio: an economic impact study. Ohio Sea Grant Publication. Columbus, Ohio.

Kite-Powell, H.L., C.S. Colgan, M.J. Kaiser, M. Luger, T. Pelsoci, L. Pendleton, A.G. Pulsipher, K.F. Wellman, and K. Wieand. 2004. Estimating the economic benefits of regional ocean observing systems. A report prepared for the National Oceanographic Partnership Program. Marine Policy Center, Woods Hole Oceanographic Institution.

Lazo, J.K. and L.G. Chestnut. 2002. Economic value of current and improved weather forecasts in the US household sector. Report prepared for NOAA. Stratus Consulting, Boulder, CO.

Leeworthy, V.R. and P.C. Wiley. 2001. Current participation patterns in marine recreation. National Survey on Recreation and the Environment 2000. NOAA, Silver Spring, MD.

Nordhaus, W.D. 1986. The value of information. In: R. Krasnow, ed., *Policy aspects of climate forecasting*. Proceedings of a Seminar held in Washington, D.C., March 4, 1986. Resources for the Future, Washington.

Pendleton, L. 2004. Harnessing ocean observing technologies to improve beach management: examining the potential economic benefits of an improvement in the Southern California Coastal Ocean Observing System. In: Kite-Powell *et al.* (2004).

Raiffa, Howard. 1970. *Decision Analysis: Introductory Lectures on Choices under Uncertainty*. Boston: Addison Wesley.

Schwenk, J.C. 1991. Unit costs of vessel casualty consequences. Prepared for the John A. Volpe National Transportation Systems Center as part of the Port Needs Study (see USCG 1991).

Sidman, C., T. Fik, and B. Sargent. 2004. A recreational boating characterization for Tampa and Sarasota Bays. University of Florida Sea Grant, TP-130.

United States Army Corps of Engineers (USACE). Waterborne Commerce of the United States, various years. http://www.iwr.usace.army.mil/ndc/wcsc/wcsc.htm.

United States Coast Guard (USCG). 1991. Port Needs Study (Vessel Traffic Services Benefits). DOT-CG-N-01-91. National Technical Information Service, document PB92-107697.

United States Coast Guard (USCG). 2004. Boating Statistics – 2003. COMDTPUB P16754.17. http://www.uscgboating.org/statistics/accident_stats.htm

Viscusi, W.K. 1993. The value of risks to life and health. *Journal of Economic Literature* 31:1912-46.