Estimating Economic Benefits from NOAA PORTS® Information:

A Case Study of the Columbia River

June 2010

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NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
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Estimating Economic Benefits from NOAA PORTS® Information:

A Case Study of the Columbia River

Report prepared for the Port of Portland 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
hauke@whoi.edu

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Summary

This report estimates the economic benefits derived from the Physical Oceanographic Real-Time System (PORTS®) installation on the Columbia River. The primary vehicle for the dissemination and use of Columbia River PORTS® information is the LOADMAX system of river stage (water level) forecasts. We will refer to the system in this report as LOADMAX/PORTS®.

Sources of economic benefit from Columbia River LOADMAX/PORTS® information include:

- Improved efficiency of the maritime transportation system on the Columbia River due to deeper loading of vessels and reduced transit delays
- Reduced risk of groundings, collisions, and allisions for maritime traffic on the Columbia River
- Improved environmental/ecological planning and analysis, including hazardous material spill response and river flow management/flood warnings

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 Columbia River PORTS® data by all potential users.

Our estimates suggest that about $4.9 million in direct annual economic benefits can be attributed to PORTS® data on the Columbia River with a reasonable degree of confidence. Another $2.5 million in annual benefits are less easily traced but may be linked to PORTS®; and an additional $0.1 million could potentially be realized with the full utilization of PORTS® data. Our best estimate of the presently realized quantifiable benefit from Columbia River PORTS® data is about $7.4 million/year. This estimate should be interpreted as a lower bound on total benefits flowing from PORTS® data, since not all uses of these data can be quantified.

Most of these benefits are in the nature of avoided costs (increased producer surplus, or profit) for commercial maritime operations on the Columbia River, primarily the operators of dry bulk vessels carrying export cargos of grain and other products, and container vessels.

confidence level	*source of benefit*	*nature of benefit*	*approx. annual value (2009 $)*
High confidence reasonably good confidence and/or direct evidence for benefits	increased draft, outbound cargo	efficiency (surplus)	$4,000,000
	reduced delays, commercial vessels	avoided costs (surplus)	$800,000
	improved spill response (present practice)	avoided costs (surplus)	$100,000
Subtotal – high confidence benefits			**$4.9 million**
Lower confidence more significant assumptions required to estimate benefits; less direct evidence	avoided accidents, commercial vessels	avoided costs (surplus)	$1,500,000
	improved river flow management and flood warnings during major flood events	avoided costs (surplus)	$1,000,000
Subtotal – lower confidence benefits			**$2.5 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)	$100,000
	enhanced recreational boating	non-market consumer surplus	--
Subtotal – potential or speculative benefits			**$0.1 million**
Non-quantified benefits	Educational use	non-market	N/A
	Scientific research	non-market	N/A

Table 1: Summary of Estimated Annual Benefits from Columbia River LOADMAX/PORTS®

Introduction

NOAA Physical Oceanographic Real-Time Systems (PORTS®) are near-shore ocean observing systems now operating in twenty locations around the United States (http://tidesandcurrents.noaa.gov/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, barometric pressure, salinity, bridge air gap, and air and 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, 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 Gross Domestic Product (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, quality control, 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 a 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 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 Search and Rescue (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. Also, not all of these benefit categories are relevant to every PORTS® installation; for example, there may be instances where a PORTS® system does not materially contribute to local or regional weather forecasting.

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.

Economic Benefits from Columbia River PORTS®

Background: Columbia River and LOADMAX/PORTS®

The Columbia River and the Ports of Portland and Vancouver are an important gateway for shipping cargos into and out of the United States' west coast. About 60 million tons of oceangoing cargo move up and down the Columbia River in about 4,000 ship transits each year.

The Columbia River has been dredged for commercial navigation since the 1860s. It is presently maintained to a controlling depth of 40 feet, and projects recently completed or now underway will increase this to 43 feet by late 2010. The controlling depth on the Columbia River Bar is 55 feet, but often, large swells on the bar impose operating limitations well short of this.

Water levels in the Columbia River are affected by river flow (the amount of water entering the river upstream of Portland) and by tides. The tide range at Portland is usually on the order of two feet; this increases to about eight feet near the mouth of the River. Minimum water levels (low tide) at the Portland/Vancouver terminals are typically about six feet above zero stage during high flow months (December to May/June) and two feet above zero stage from July to November (Figure 1). Day-to-day changes in daily minimum water level can exceed one foot. River current rates are typically 1-2 knots on the flood and 3-4 knots on the ebb, but can reach 6 knots on the ebb in some cases.

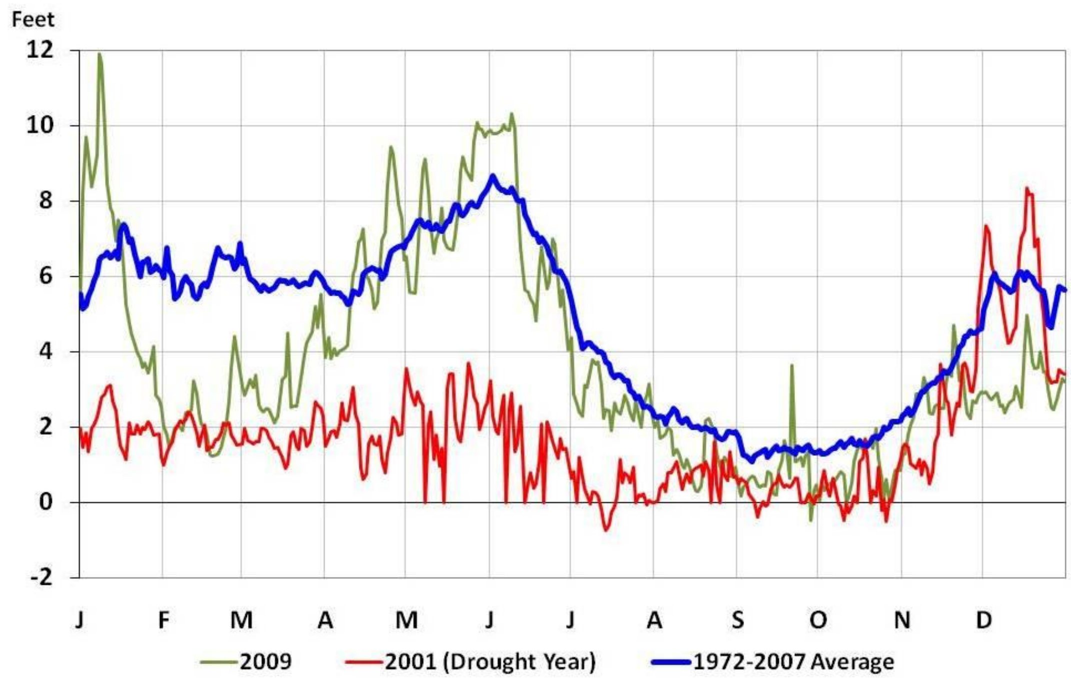

Figure 1: Daily minimum Columbia River water level at Vancouver
Source: Port of Portland

Draft-constrained vessels transiting the Columbia River have to adjust their loading and/or the time of their transit to allow for two feet of under-keel clearance on the River and three feet (rising tide) or four feet (falling tide) of clearance on the Columbia River Bar. An outbound voyage from Portland to the river mouth usually takes six to eight hours. To cross the bar on a rising tide, vessels leaving Portland have to pass the low water point somewhere en route on the River. On western sections of the River, this low water point can represent river stage levels within two feet of zero even during period of high river flow (Figure 2).

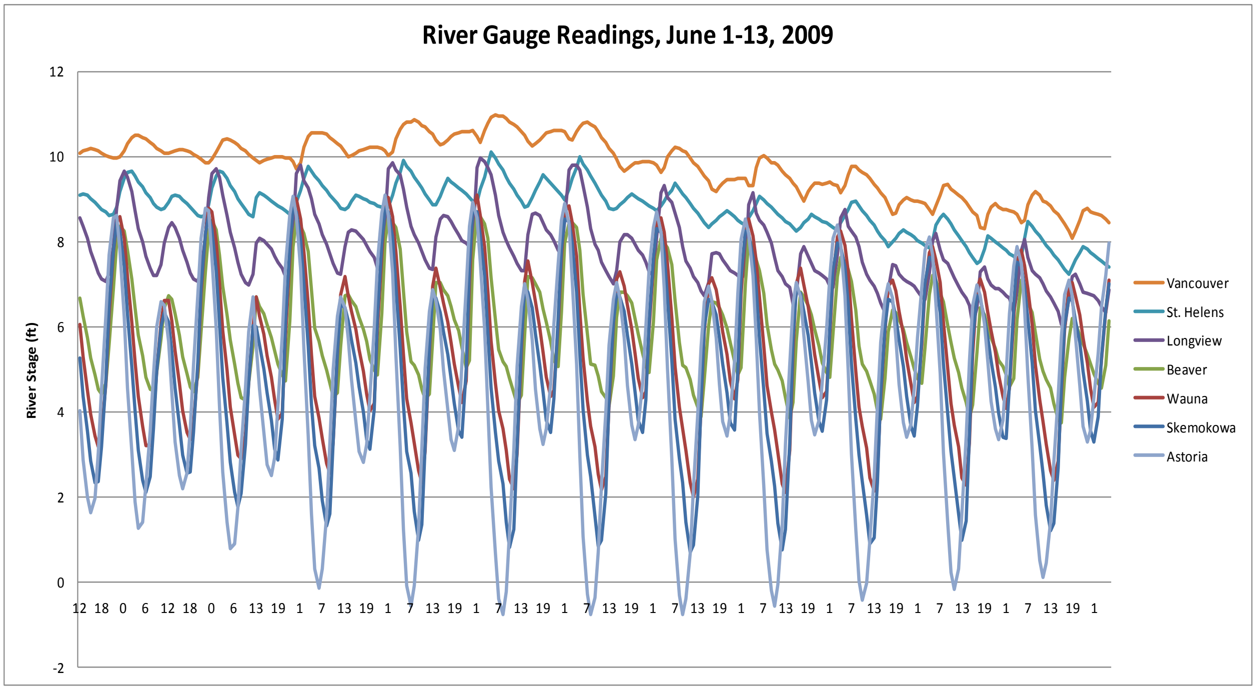

Figure 2: Water levels on the Columbia River for the first two weeks of June 2009
Source: LOADMAX data sheets

This combination of factors implies that, to maintain two feet of under keel clearance with a controlling channel depth of 40 feet at zero river stage, water level considerations will affect the timing and loading of most transits of draft 38 feet and greater. During times of low flow, transits at drafts of 36 to 38 feet can also be constrained.

The LOADMAX and Physical Oceanographic Real-Time System (PORTS®) on the Columbia River is a public information acquisition and dissemination technology operated in partnership by NOAA and the Port of Portland. It consists of six river gauges measuring water level and a river forecast system operated by the National Weather Service (NWS) Northwest River Forecast Center. The system was first deployed as LOADMAX in 1984/85, and became a NOAA PORTS® system in 2006/07. Its configuration has remained constant since its inception, and an additional river gauge is presently being added at Hammond.

The LOADMAX/ PORTS® system currently produces daily forecasts of river stage and velocity at one hour intervals, with a forecast horizon of 10 days, at 10 sites and between Portland and a point about 18 miles above the River mouth (Figure 3). These forecasts are based on a 1-D model of river flow and stage. The Northwest River Forecast Center also produces an extended 4 to 5 month forecast in June of each year of the anticipated low water periods during the low water season (usually July to October).

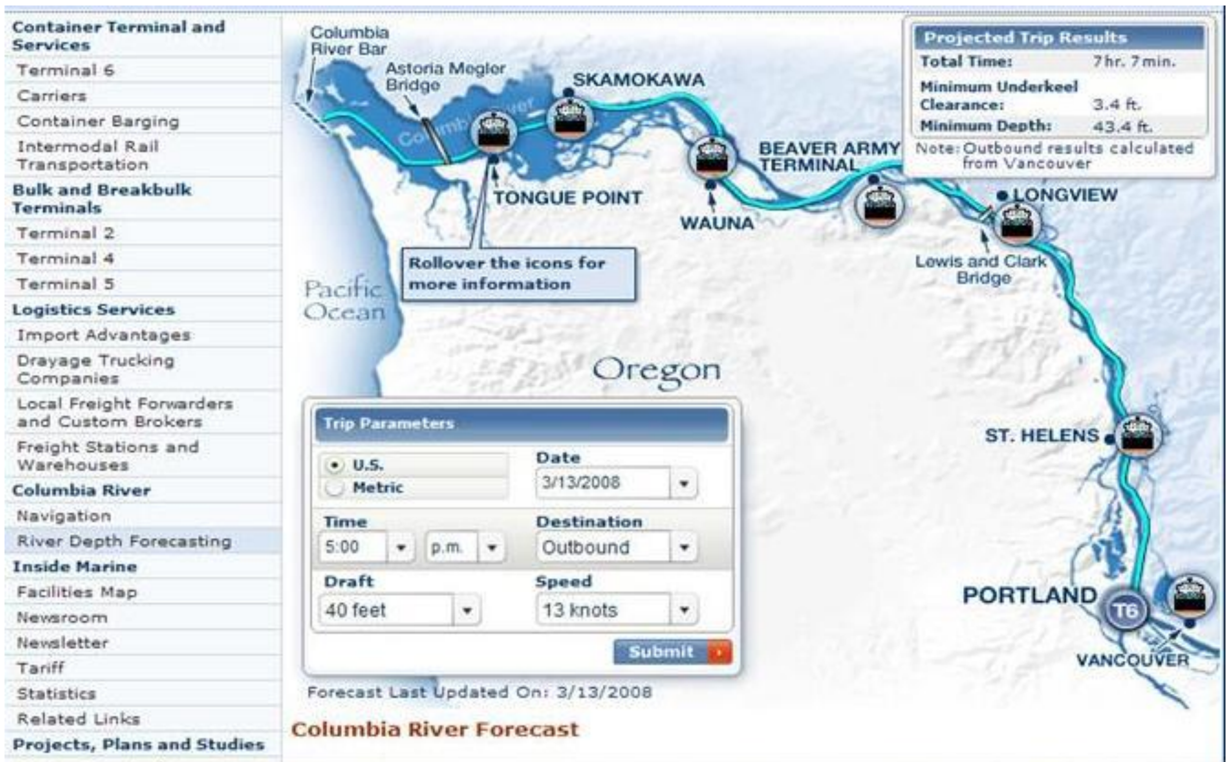

Figure 3: Columbia River LOADMAX/PORTS® information display.
Source: http://www.portofportland.com/Nvgt_Rvr_Frcst.aspx

General Notes on Value of Columbia River PORTS®

The primary user of Columbia River LOADMAX/PORTS® data is the commercial shipping community – the vessel operators and pilots who manage the movement of some 2,000 ocean-going vessels (4,000 annual arrivals and departures) and another 1,000 or so inter-ports movements on the River. Benefits are generated in two main ways: by allowing operators to maximize the loading of ships (mainly outbound dry bulk carriers) to take advantage of true river water levels, and by reducing delays that might affect vessel movements if future water levels were not predicted accurately. Columbia River pilots indicate that in the absence of PORTS® information, they would have to apply greater safety margins on both loading and transit timing decisions, both of which are costly to vessel operators. Both River Pilots and Bar Pilots routinely use LOADMAX/PORTS® in planning and executing most vessel movements.

Additional sources of benefits are likely to be avoided accidents (groundings and collisions) on the River and an improved capacity for hazardous material spill response.

Efficiency

Increased cargo carried per transit

Most of the cargo shipped via the Columbia River is outbound agricultural bulk commodities (grains, corn, soy beans) carried in Handymax and Panamax bulkers, primarily to destinations in Asia. Some 40% of all US wheat exports are shipped via the Columbia River. Potash is also exported via the River. Import cargos include steel, gypsum, cement, cars, and containerized goods. Container vessels also take on board export cargo including agricultural products, clay, and scrap material.

Most draft-constrained transits on the River involve outbound dry bulk and container ships. The average draft carried on the River has increased over time for both categories of vessels (Figure 4), and so have the percentage and absolute number of transits in the 38 to 40 foot draft range (Figures 5). In recent years, about 250 dry bulk ships and 30 container ships transited the River annually at drafts in excess of 38 feet. In addition, about 80 dry bulk ships and 30 containerships transited at drafts between 36 and 38 feet. Container ships often run at deeper draft outbound because the export cargos tend to be denser than imports (mainly manufactured goods).

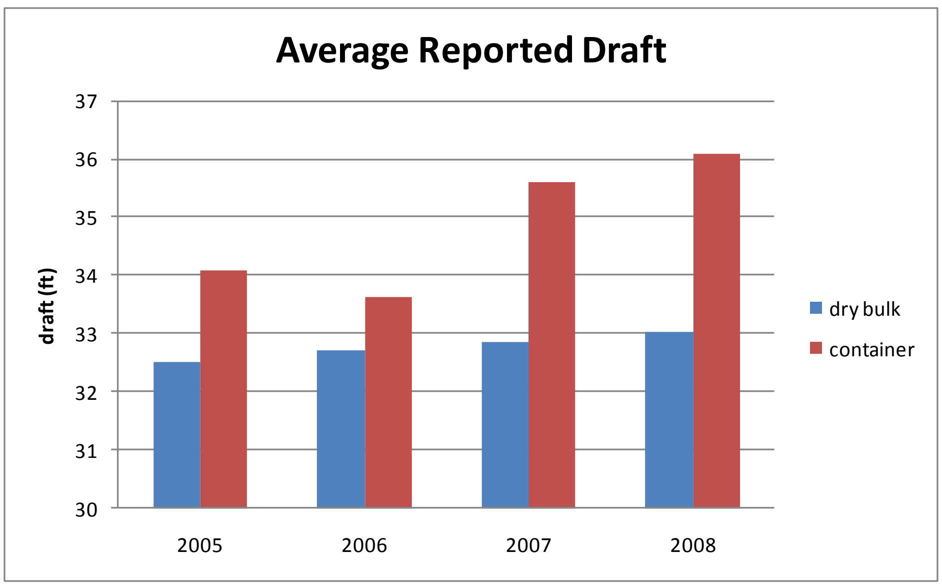

Figure 4: Annual trends in average reported draft for dry bulk and container ships. Data: Columbia River Pilots

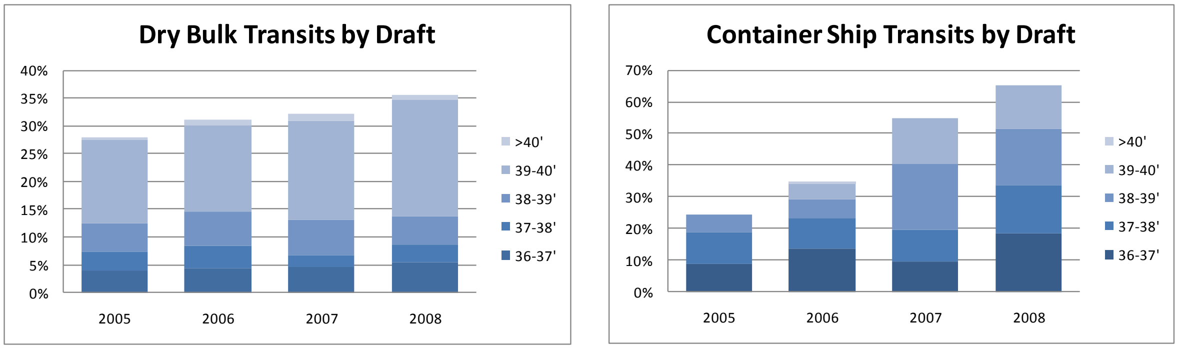

Figure 5: Annual trends in percentage of high-draft dry bulk and containership draft transits.
Data: Columbia River Pilots

In interviews, both pilots and terminal operators indicate that water level forecasts are routinely used to make decisions about loading and draft, especially on outbound dry bulk transits. This anecdotal information is supported by data correlating transit drafts with river water levels. Figure 6 shows the long-term average daily minimum river stage at Vancouver together with the percentage of transits operating at draft greater than 38 feet over the course of the year. Figure 7 shows the number of transits per month in excess of 38 feet draft for 2008. These plots support the claim that significant numbers of vessels on the Columbia River actively seek to maximize draft and take advantage of seasonal and short-term fluctuations in water level to that end.

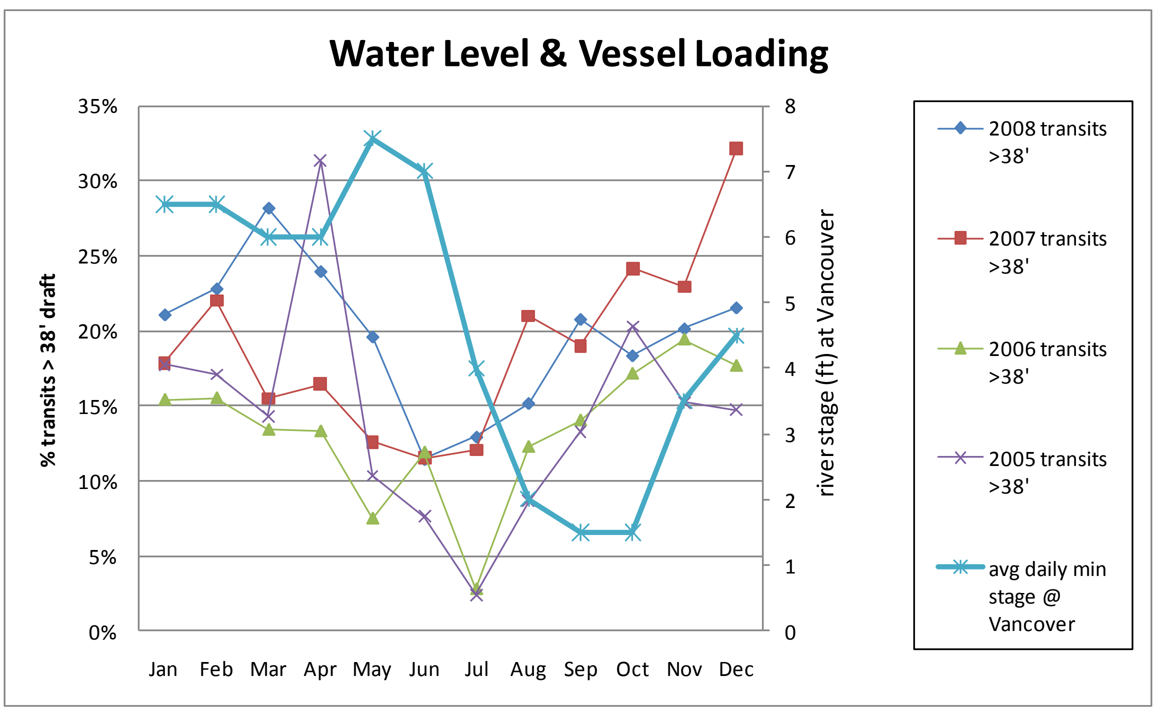

Figure 6: Columbia River water level and percentage of transits above 38’ draft
Data: Columbia River Pilots

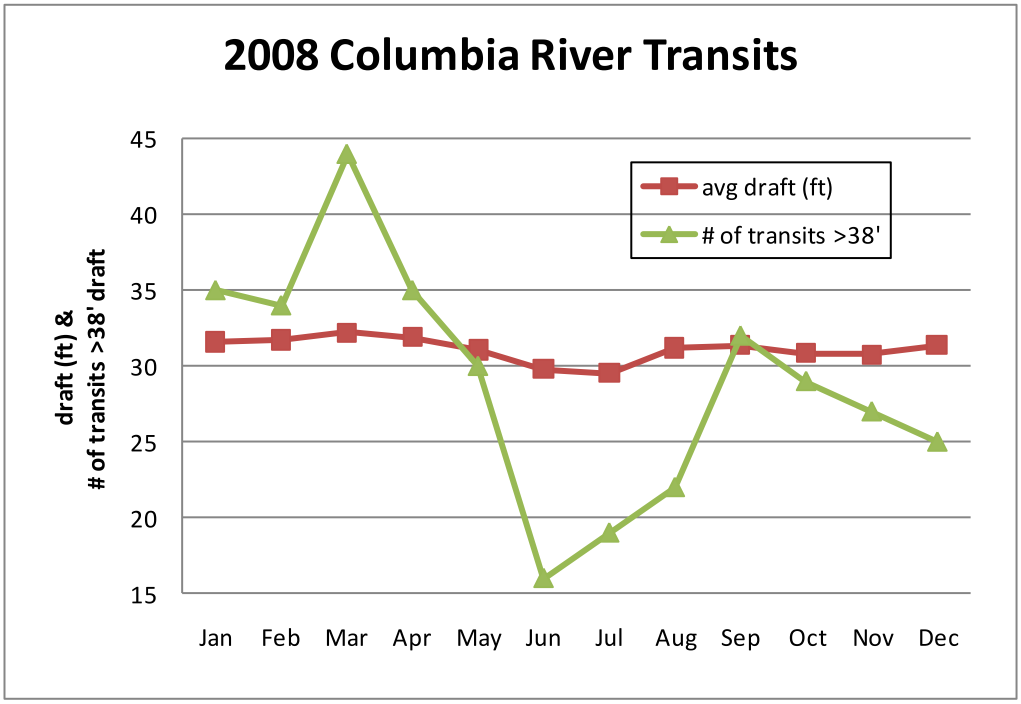

Figure 7: Seasonal change in transits above 38' draft, 2008.
Data: Columbia River Pilots

Based on these data and discussions with terminal operators and pilots on the River, we estimate that half of the outbound dry bulk and container ship transits carrying drafts of 36 feet and greater are loaded deeper than they might otherwise be, because of the availability of LOADMAX/PORTS® data. Increased loading can result in 12 inches or more of additional draft on such transits (USACE 1999).

Most of this activity is represented by about 150 dry bulk transits. A good proxy for the economic benefit derived from the ability to carry increased draft is the expected cost savings associated with moving a fixed cargo volume with a reduced number of voyages. For a particular trade and vessel type, this can be estimated as:

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

where

AV = annual benefit ($)
AD = additional draft enabled by PORTS® information (inches)
TPI = tons per inch immersion
AC = average cargo carried per ship transit without PORTS® (tons)
NC = number of transits/year affected by PORTS®
RT = average round trip distance (nm)
SC = operating cost at sea ($/hr)
KTS = vessel speed (knots)

DOC = docking and undocking time per transit (hours)
LR = loading/unloading rate (tons/hr)
PC = operating cost in port ($/hr)

Using this approach, and the assumptions summarized in the Table 2 below, we estimate the annual potential benefit to dry bulk loading decisions from LOADMAX/PORTS® data during recent years on the Columbia River at about $2.8 million.

Parameter	***Variable***	***Value***
Additional draft enabled by PORTS® information (inches)	AD	12
Tons per inch immersion	TPI	90
Average cargo per transit (tons)	AC	60,000
Number of transits/year affected by PORTS® data	NC	150
Average round-trip distance (nm)	RT	15,000
Operating cost at sea (incl. fuel) ($/hr)	SC	1,000
Vessel speed (kts)	KTS	15
Docking and undocking time per transit (hours)	DOC	24
Loading/unloading rate (tons/hr)	LR	1,200
Operating cost in port ($/hr)	PC	300

Table 2: Assumptions for estimating benefits from increased dry bulk loading

In addition to the dry bulk transits, we estimate based on transit data and discussions with terminal operators that some 30 outbound container ship transits per year benefit from the ability to load additional cargo due to LOADMAX/PORTS® information. At an average additional loading of 20 containers and an economic value per box moved of $2,000, this represents an annual benefit of $1.2 million.

Reduced delays

Although data on vessel delays during transits of the Columbia River are not available, both pilots and terminal operators routinely make use of LOADMAX/PORTS® data to time transits of the river and minimize delays on both up-bound and down-bound trips. In some cases, up-bound transits are able to avoid waiting for maximum tide in this way; there are some draft-limited inbound vessels, such as gypsum carriers, that must time up-river transits carefully. More often, timing issues arise for outbound transits, in part because the Columbia River Bar Pilots require large vessels to transit the bar on a rising tide in most circumstances.

We estimate based on these discussions and transit draft data that the use of water level forecasts affects the timing of about 10% of transits on the River (400 vessel movements/year), and reduces delays on average for these transits by 60 minutes. At an average total in-port cost of $2,000/hr (USACE Deep Draft Vessel Costs, various years), this translates to $800,000/year in operating cost savings.

Improved SAR performance

There is very little Search & Rescue (SAR) activity on the Columbia River. LOADMAX/PORTS® information does not play a significant role in planning or execution of SAR activities.

Safety

Groundings and Collisions, Commercial Vessels

Data on commercial vessels grounding are available from the US Coast Guard's accident databases CASMAIN (1981-90) and MSIS (1992-present). In Figures 8 and 9, these data are combined with transit data from the Columbia River Pilots and from the US Army Corps of Engineers Waterborne Commerce Statistics annual summaries to show grounding and collision rates on the Columbia River. For our purposes, a "transit" is a vessel movement, so that a port call usually consists of two transits: one upriver and one downriver.

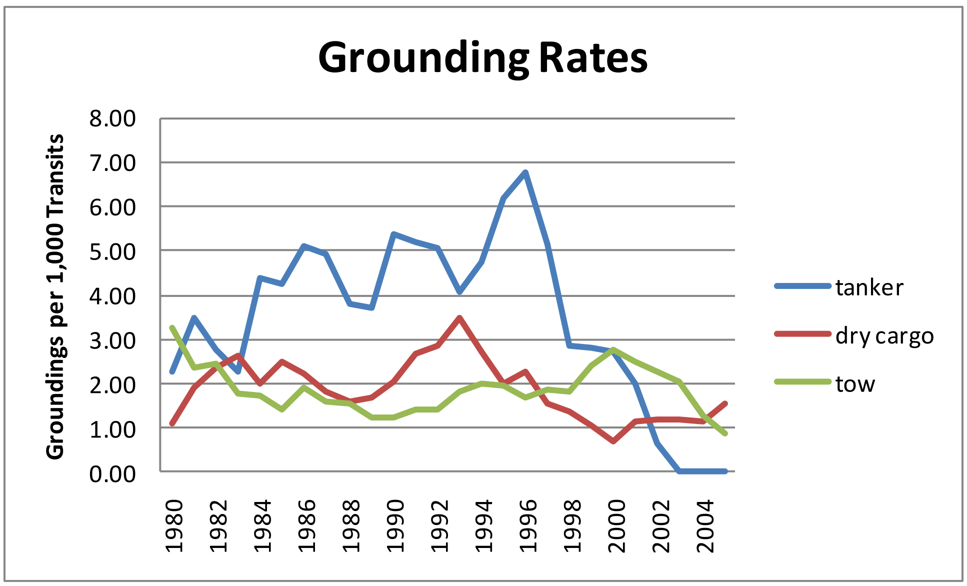

Figure 8: Grounding rates for commercial vessels on the Columbia River, 5-point moving average.
Data: USCG, Columbia River Pilots, USACE

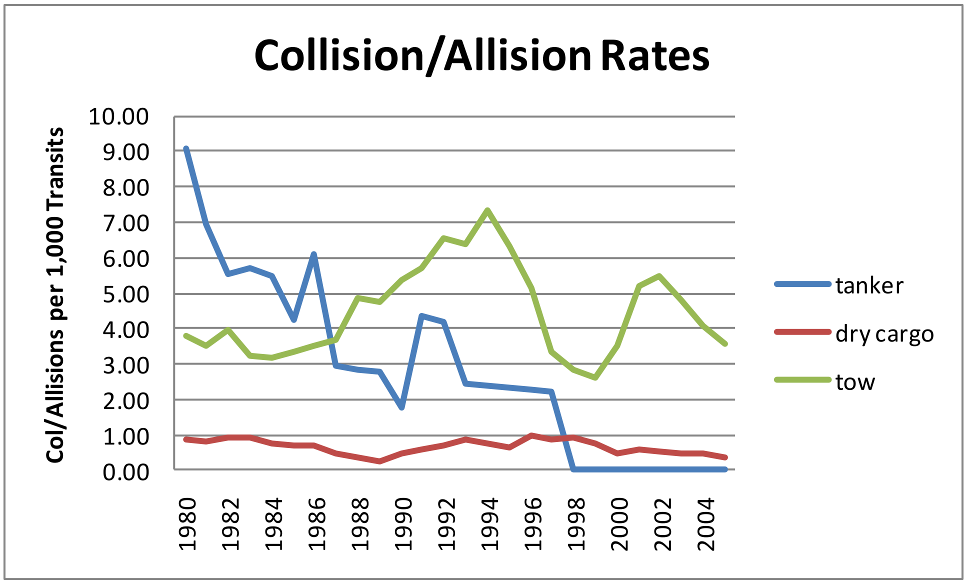

Figure 9: Collision/allision rates for commercial vessels on the Columbia River, 5-point moving average. Data: USCG, Columbia River Pilots, USACE

These data suggest that the risk of grounding on the Columbia River increased during the 1980s, and began to decrease in the early to mid 1990s, for both tankers and dry cargo vessels. The risk of a collision or allision has declined steadily for tankers since the early 1980s but has not changed significantly for dry cargo vessels. There is no clear trend in accident rates for tug/tows and barges.

Accident rates on the Columbia River, especially for collisions/allisions, are relatively low compared to other major US ports. These rates are affected by many factors, including changes to channel configuration (dredging), changes in vessel size (and draft), and changes in operating procedures and information – including the availability of LOADMAX/PORTS® data. Discussions with pilots and USCG officers on the River support the view that the LOADMAX/PORTS® information plays a role in helping River traffic maintain this good safety record while maximizing the efficient use of the river in terms of vessel draft and transit timing.

In particular, the reduction in grounding rates for dry cargo vessels since the early 1990s, from two or three groundings to one grounding per 1,000 transits, coinciding with increasing transit drafts (see above), is credited by pilots in part to the availability of LOADMAX/PORTS® on the Columbia River. While it is not possible to assign a specific effect to a specific cause with certainty in this case, it is plausible that LOADMAX/PORTS® may contribute 25 to 50% of this reduction in grounding risk. We therefore credit LOADMAX/PORTS® data with reducing the grounding rate for dry cargo vessels (dry bulk and container ships) by 0.5 groundings per 1,000 transits – or about 1.5 groundings/year.

The economic loss associated with a vessel 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.

To estimate of the cost of groundings, a similar approach was used 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, 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 grounding on the Columbia River is about \$0.5 million for dry cargo vessels. This average takes into account the distribution of vessel size and cargo, and also reflects seasonal averages for environmental losses. Using the assumptions described above, the reduction in grounding risk due to LOADMAX/PORTS® translates into an estimated \$1.5 million in avoided costs per year.

Environmental Protection: improved spill response

Hazardous material spills are rare on the Columbia River; the most recent significant spill involved a tanker that hit a rock in the River in 1981. Based on the spill history and discussions with USCG and spill response officials, we estimate the likelihood of a 100,000 gallon oil spill on the River at present at less than 5 percent/year.

Although no assessment specific to the Columbia River has been carried out, results from damage assessment models for other locations around the United States suggest that damages associated with a spill of this magnitude on the Columbia River might be on the order of \$25-50 million (USCG 1991; Vanem *et al.* 2008; Yamada 2009). 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. However, spill response officials acknowledge that location-specific water current is critical to predicting the spill trajectory and planning an effective containment response. If we assume a 5% reduction in damages due to the use of PORTS® data in spill response activities, the expected annual benefit on the Columbia River is about \$100,000.

According to spill response officials, present technology and practice typically allows for the recovery of about 10 percent of spilled oil (Watabayashi, p.c.). 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, but only to a limited extent 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.). If this can be achieved, environmental damages may be reduced by an additional 5% or so. On the Columbia River, using the above assumptions, that means another \$100,000/year in expected avoided losses.

Flooding Forecasts and Warnings

The water level information from Columbia River LOADMAX/PORTS® gauges is used by the National Weather Service to issue forecasts and warnings related to possible flooding along the River (A. Bryant, NWS, p.c. 2010). During times of high water on the River, NWS monitors gauge readings continually and may update flooding forecasts several times per day. Observations such as those provided by the LOADMAX/PORTS® gauges are a prerequisite for NWS to issue forecasts.

The last two major flooding events in the Portland District of the US Army Corps of Engineers occurred in 1964 and 1996. Estimates of damage to buildings, roadways, and farm land from flooding during the 1996 event in Oregon exceed $280 million. Water flow on the Columbia River is managed actively to minimize flooding, and is estimated to have helped avoid more than $3 billion in additional damage in 1996 (USACE 1997).

No simulation exercises have been carried out to quantify the difference that the availability of LOADMAX/PORTS® gauge information makes to river flow management and flood warnings during high water events. If we assume that a flooding event capable of causing $3 billion in damages along the Columbia River occurs every 30 years, and that LOADMAX/PORTS® information helps improve river flow and flood warning decisions such that costs are reduced by 1% more of the potential total, this translates to an average annual benefit on the order of $1 million.

We consider this to be a low confidence estimate because neither the present flooding damage risk nor the contribution of LOADMAX/PORTS® data to its mitigation has been estimated carefully.

Enhanced Value of Recreation Activities

The Columbia River is used for recreational boating and fishing. In principle, water level and river flow information can be of value to recreational users. However, conversations with representatives of the recreational boating and fishing communities lead us to conclude that at present, awareness and use of LOADMAX/PORTS® information by the recreational community is minimal. It is possible that, in this setting, the extent of day-to-day variation in water levels and flow rates, while important to commercial users of the River, is not sufficiently large to warrant its use by boaters and fishermen.

Use of Data in Scientific Research and Education

LOADMAX/PORTS® data are useful in several areas of scientific research and education because they represent an accurate and continuous time series of water level and river flow information spanning more than 25 years. Although it is difficult to assign an economic value to this use of the data, it is important to recognize that a number of research projects related to river and coastal ecosystems could not be carried out as they are at present without this data set.

For example, Dr. David Jay and colleagues in the Hydrodynamic Processes and Ecosystems Group in the Department of Civil and Environmental Engineering at Portland State University use LOADMAX/PORTS® data to improve the scientific understanding of river flow and other hydrodynamic processes on ecosystem features ranging from salmon to tides and sediment transport (http://web.cecs.pdx.edu/~jaylab/). LOADMAX/PORTS® data have also been used by Dr. Antonio Baptista of the Center for Coastal Margin Observation and Prediction at the Oregon Health and Science University for research on the influence of river flow on coastal ecosystems and continental shelf processes (http://www.stccmop.org/).

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Final responsibility for the estimates presented in this report rest with the author.

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