Engineering Data Sheet

6277

Product: Optimum North and South American Sites For Dolphin™ Offshore Integrated Tidal Power Generation

Historical Background:

The North American site with the greatest tides (tidal range) is the Bay of Fundy off the eastern coast of Maine.

The Bay of Fundy's Minas Basin
Highest Tides in the World

The highest tides on earth occur in the Minas Basin at the most northeastern extremities of the Bay of Fundy.

The tides on Earth are strongly influenced, in addition to astronomical factors, by the sizes, boundaries, and depths of ocean basins and inlets, and by Earth's rotation, winds, and barometric pressure fluctuations. Tides typically have ranges (vertical high-to-low) of a meter or two, but there are regions in the oceans where various influences conspire to produce virtually no tides at all, and others where the tides are greatly amplified. Among the latter regions are the Sea of Okhotsk, the northern coast of Australia, the Bristol Channel on the west coast of England, and in Canada at the Ungava Bay in northern Quebec, and the Bay of Fundy between New Brunswick and Nova Scotia. The tidal ranges in these regions are of the order of 10 meters. The much larger Ungava Bay cannot be yet considered as it is covered by ice for several months each year. The number of ice free days is increasing due to climate change and could become considered in the future if climate change continues undamped.

The highest tides on Earth occur in the Minas Basin, the eastern extremity of the Bay of Fundy, where the average tide range is 12 meters and can reach 16 meters when the various factors affecting the tides are in phase (although the highest tides occur typically a day or two after the astronomical influences reach their peak).

The primary cause of the immense tides of Fundy is a resonance of the Bay of Fundy-Gulf of Maine system. The system is effectively bounded at this outer end by the edge of the continental shelf with its approximately 40:1 increase in depth. The system has a natural period of approximately 13 hours, which is close to the 12 hour-25 minute period of the dominant lunar tide of the Atlantic Ocean.

Like a father pushing his daughter on a swing, the gentle Atlantic tidal pulse pushes the waters of the Bay of Fundy-Gulf of Maine basin at nearly the optimum frequency to cause a large to-and-fro oscillation. The greatest slosh occurs at the head (northeast end) of the system. Because Earth rotates counterclockwise in the Northern Hemisphere, the tides are higher in Minas Basin (Wolfville-Truro area) than in Chignecto Bay (Amherst-Moncton area).

Although it is the gravitation of the Moon and Sun that raises the tides, the energy in the churning waters is extracted from the rotational energy of Earth spinning on its axis. Near Annapolis Royal, Nova Scotia, a tiny portion of this energy is being converted into commercial electrical energy in the only tidal power plant in the Western Hemisphere. The peak output of the Annapolis Basin generator is 20 megawatts, about 1% of Nova Scotia's electrical power capacity.

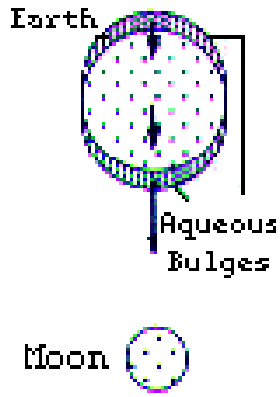
Tidal friction both lengthens the day and increases the size of the orbit of the Moon. The day is lengthening by about 1 second every 50,000 years, imperceptible on a human time scale, but of profound significance to Earth's rotation over a few billion years. If the Sun does not first incinerate our planet, in the distant future there will come a day that is as long as the lunar month (each then equal to about 40 present days) and a more distant Moon will stand stationary in the sky, as does Earth now in the lunar sky. But this situation will not endure, for solar tides will still be present and will cause the Moon to approach Earth once more.

Wolfville is located on the southern shore of Minas Basin, the northeast arm of the Bay of Fundy. The Bay of Fundy is noted for its large tides, and it is on Minas Basin that the highest tides on Earth occur. This is truly a wonder of the world and should be experienced by any visitor to the Wolfville area.

Well before low tide is reached, Wolfville's small harbor is literally empty. Four km west of Wolfville, at the Port Williams bridge and wharf, the large vertical range of the tides may be seen to better advantage (a parking lot is located on the Wolfville side of the bridge). Dramatic views of the tidal rise and fall are also available town of Hantsport (located 16 km east of Wolfville in the foot of William Street). Views of the vast areas of sea bottom uncovered by the falling tide may be had at Evangeline Beach and at Avonport Beach, both about 8 km east of Wolfville. In late July and August, the extensive intertidal flats in these areas are visited by hundreds of thousands of shorebirds on their annual migration from the Arctic to South America. The crustaceans and worms in these mudflats provide a rich source of food for these birds which then fly for three to four days non-stop to South America. Flocks of shorebirds are best seen within two hours of high tide when they are spectacularly concentrated along the upper limits of the beaches.

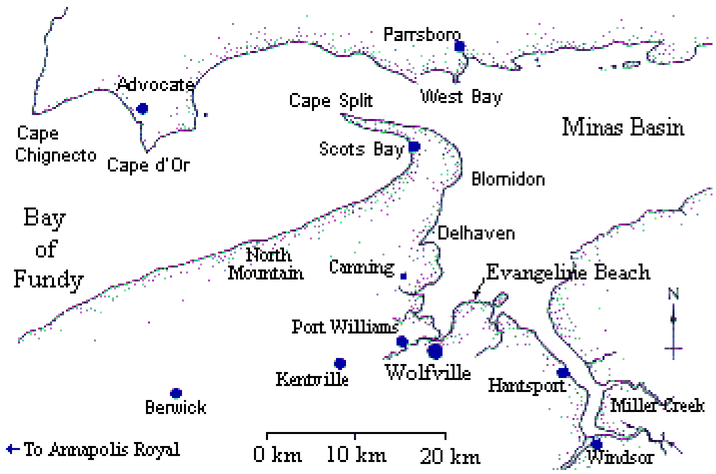
Large areas of the original flats now lie behind man-made dykes. This conversion of tidal flats into rich farmland began with Acadian settlers in the seventeenth century. Today long dykes and thousands of hectares of productive level fields may be seen in the vicinity of Grand Pre, Wolfville, Port Williams and Canard. Near the mid-point of an incoming tide, a tidal bore may be seen tumbling upsteam in some of the rivers which flow into Minas Basin (e.g. the St. Croix and Meander rivers near Windsor, and the Shubenacadie and Salmon rivers near Truro). A bore forms where the incoming tide pushes its way upstream against the outgoing freshwater flow of the river.

Perhaps the most awesome display of the tides on our planet occurs at Cape Split, on the southern side of the entrance to Minas Basin (Cape Split may be reached by a pleasant two-hour walk along a popular hiking trail from the village of Scots Bay, which is a 30-minute drive north of Wolfville). Here at the time of the mid-point of an incoming tide, for a considerable distance the forest on the towering cliffs is filled with a hollow roar produced by the turbulence of the waters surging over the submarine ridges below. The currents exceed 8 knots (4m/s), and the flow in the deep, 5 km-wide channel on the north side of Cape Split equals the combined flow of all the streams and rivers of Earth (about 4 cubic kilometres per hour). Three hours later the spectacle pauses, and then begins flowing in the opposite direction.



Tides were known to the ancients, but an understanding of their origin came only three centuries ago with the publication of Issac Newton's Principia. Tides originate in the fact that the force of gravity decreases with distance from a massive body. The Moon exerts a force on the Earth, and Earth responds by accelerating toward the Moon; however, the waters on the side facing then Moon, being closer to the Moon, accelerate more and fall ahead of Earth. Similarly, Earth itself accelerates more than the waters on the far side and falls ahead of these waters. Thus two aqueous bulges are produced, one on the side of Earth facing the Moon, and one on the side facing away from the Moon. As Earth rotates on its axis beneath these two bulges, the rise and fall of the oceans results. If Earth had not rigidity, the entire planet would flex freely in the same fashion, the ocean bottoms would also rise and fall, and there would be virtually no water tides. The very existence of the tides indicates that on a time scale of several hours, our planet displays considerable rigidity.

Although the Sun exerts a gravitational force 180 times as strong as does the Moon on Earth, because the Moon is so much closer, the variation in Moon's force across Earth's diameter is about 2.2 times larger than the variation in the Sun's force. As noted above, it is this variation that produces tides, thus the pair of bulges raised by the Moon are considerably larger than the pair of tidal bulges get in and out of step, combining in step to produce "spring" tides (no connecton with the season) when the Moon is new or full, and out of step to produce "neap" tides when the Moon is at first or last quarter. Another factor having a substantial influence on tidal ranges is the elliptical shape of the Moon's orbit. Although the Moon is only 9 to 14% closer at its close point to Earth (perigee) than at its far point (apogee), because the variation in its gravitational force varies inversely as the cube of its distance (the force itself varies inversely as the square of the distance), the Moon's tidal influence is 30 to 48% greater at perigee than at apogee. In the Bay of Fundy the perigee-apogee influence is greater than the spring-neap influence. Although the variation of the Moon's distance is not readily apparent to observers viewing the Moon directly, to observers near the shores of Minas Basin, the three to six meter increase in the vertical tidal range makes it obvious when the Moon is near perigee, clear skies or cloudy!



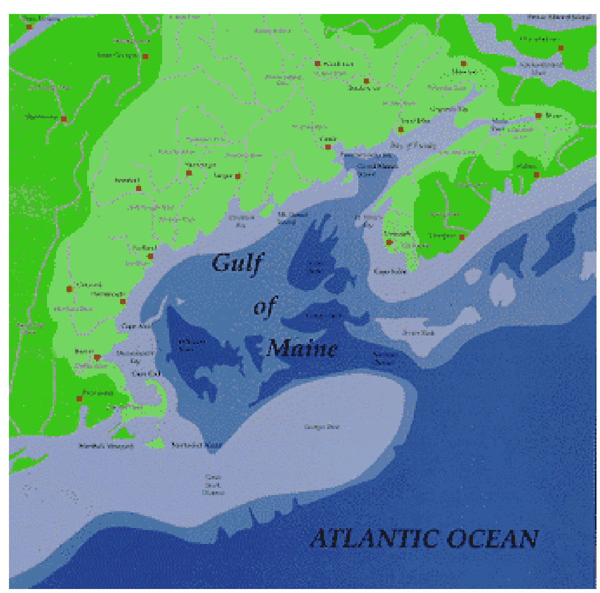
The Magnificent Minas Basin

- The vertical rise and fall of the tide: Hantsport, wharf at the foot of William Street, and the Port Williams Wharf.
- A ship high and dry at low tide: Hantsport wharf at the foot of William street.
- Vast tidal flats exposed at low tide: Evangeline Beach and Delhaven.
- Turbulent tidal rip current: Cape Split, at the mid-point of an incoming tide and Cape d'Or, at the mid-point of an incoming tide.
- Tidal current equal to all the rivers on Earth combined: Looking north from Cape Split at mid-tide and looking south from the West Bay road at mid-tide.
- Tidal Bore: St. Croix River (Tidal View Farm at Miller Creek) occurs about 3 hours and 15 minutes after low tide. Meander River bridge between Sweet's Corner & Mantua occurs about 3 hours and 45 minutes after low tide.
- The only tidal electric generating station in the Western Hemisphere is between Annapolis Royal and Granville Ferry.

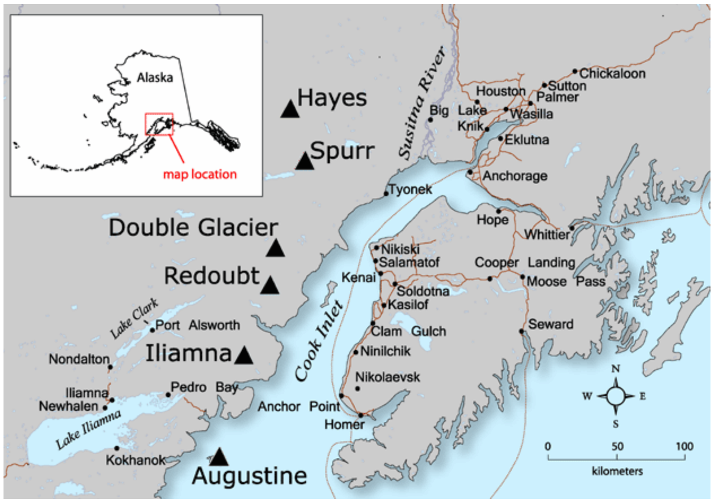
Quick Facts on Tides

- The highest tides on planet Earth occur near Wolfville, in Nova Scotia's Minas Basin. The water level at high tide can be as much as 16 meters (45 feet) higher than at low tide! The difference is referred to as **Tidal Range**.
- Small Atlantic tides drive the Bay of Fundy/Gulf of Maine system near resonance to produce the huge tides. High tides happen every 12 hours and 25 minutes (or nearly an hour later each day) because of the changing position of the Moon in its orbit around the Earth.
- Near mid-tide at Cape Split, one may hear the "voice of the Moon" in the form of the roar emitted by turbulent tidal currents. At mid-tide, the flow in Minas Channel north of Blomidon equals the combined flow of all the rivers and streams on Earth.
- Nova Scotia bends when the tide comes in. As 14 billion metric tons (14 cubic kilometres) of sea water flow into Minas Basin twice daily, the Nova Scotia countryside actually tilts slightly under the immense load.
- In mid-summer, crustaceans in the intertidal mudflats provide a crucial source of food for hundreds of thousands of migrating shorebirds.
- The waters of the Minas Basin appear muddy, because the strong tidal currents cause erosion of the red soils along the shoreline and this soil is suspended in the water.
- When the tide is coming in, tidal bores (which look like a wave traveling against the flow of the river) surge up several rivers which flow into the Minas Basin. Some great tidal bores can be seen on the St. Croix, Meander, Shubenacadie, Maccan and Salmon Rivers.

The Bay of Fundy and Gulf of Maine, with a total area of about 180,000 km^2 and depths of generally less than 200 meters, are a part of the Continental Shelf off eastern Canada and New England. The area of the Bay of Fundy alone is about 16,000 km^2. Its name is likely a corruption of the French *fendu* ("split"). It was known for a time as La Baie Françoise. Between about 15,000 and 10,000 years ago, as the glaciers retreated from the last ice age, parts of **GEORGES BANK** and other shallow areas were dry land. Fragments of trees and mammoth teeth from this era are still found occasionally in fishing trawls. A rising sea level since then not only submerged these offshore banks, but also led to the development of the present tidal regime.



The North American site with the second greatest tides (tidal range) is the Cook Inlet located on the south central Alaskan Coast.



Cook Inlet, Alaska

Cook Inlet lies on the south central Alaskan Coast and has been the center of a thriving oil and gas industry for almost 50 years. Oil was first discovered in 1957 onshore at Swanson River (80 km SW of Anchorage) and in 1963 oil was discovered offshore in the center of Cook Inlet. Anchorage, located at the head of Cook Inlet, is Alaska's largest city (population of 260,000) and a major sea port. Other towns in Cook Inlet are Kenai (population of 6,900) and Nikiski (population of 4,300). Comparatively, Prince Rupert (as the largest city in the QCB area) is also a major seaport but only has a population of about 17,000 residents. The population of the Queen Charlotte Islands in total is about 6,000. The Cook Inlet area supports a much larger population base than does the QCB. Both are enclosed waterways. Cook Inlet is a tidal estuary and the Hecate Strait is a partially sheltered shelf environment. Each has long-established commercial fisheries, a growing tourism industry, environmental concerns (protection of parks, sanctuaries, and critical habitats), First Nations interests and the concerns of how to balance all these competing and coexisting enterprises.

Many issues of concern to BC residents and environmental groups have already been dealt with in the Cook Inlet area and these can be used as a template for monitoring oil and gas activities and their effects on the environment in the QCB. One of the major steps forward in the Cook Inlet area, especially after the Exxon Valdez oil spill, was to set up councils and 'keepers' to involve the public in the monitoring of the production and transportation of oil and gas. This includes actual monitoring projects as well as education and information dissemination.

The Cook Inlet basin is about 380 km long and about 80 km wide, as defined by the outline of the area wide oil and gas sales area. Comparatively, the QCB is about 470 km in length (from the Alaska panhandle to the Scott Islands just north of Vancouver Island) and about 100 km in width.

The high-potential oil areas in both basins are about the same in length—about 200 km—but the Cook Inlet area is somewhat wider. Oil and gas were discovered on land in the Swanson River area of Cook Inlet in 1957, and in 1963 oil was discovered in the center of Cook Inlet. There are presently seven producing oil fields on the Kenai Peninsula (>30,000 barrels per day, 'bpd') and 17 gas fields (>485 million cubic feet of gas per day, 'cfgpd'), according to Alaska's Oil and Gas Association (AOGA, 2000). There are 15 platforms tapping offshore fields. These are linked by pipeline to onshore storage tanks, from which oil is transferred by tanker to the refinery at Nikiski, which also has a fertilizer plant and a gas liquefaction plant. Peak oil production occurred in 1970 with 230,000 bpd. Production had dropped to 7,000 bpd in 2003. The oil and gas industry employs more than 1500 workers, with hundreds more on contract, and contributes hundreds of millions of dollars annually to the local economy.

Physical Environment

Boyd and Shively (1999) summarize the physical environment of Cook Inlet. Offshore winds average 12-18 knots, but channeling in valleys can produce wind speeds in excess of 100 knots in inshore areas. Water depths in Cook Inlet are typically 20-40 meters (m) in the upper reaches where present oil production is focused. A central channel descends to 75 m and deepens into the lower reaches to 150 m. There is a comparatively high tidal range in Cook Inlet, with the mean diurnal range of 9 m at Anchorage. The tidal range and inlet geometries are responsible for strong currents: maximum surface currents average about 3 knots. Bottom currents of 1.5 knots are strong enough to form migrating sand waves. Currents of up to 12 knots have been recorded locally. These currents transport large amounts of glacial sediment eroded from surrounding mountains, to be deposited in tidal flats or carried offshore to the Aleutian Trench.

Cook Inlet contains ice (ice chucks from calving glaciers) from October through to April. Like the QCB, Cook Inlet lies close to a plate margin. The subduction of the Pacific Ocean plate below the North American plate causes earthquakes and volcanoes. In the Cook Inlet region there have been 99 earthquakes with magnitudes greater than 5.0 since 1899; four of these had magnitudes greater than 7.0. Some thrust faults in the oil field areas may be capable of generating earthquakes with magnitudes of 6.3-6.9. The earthquake risk is somewhat higher than that in the QCB. Active volcanoes lie on the western flank of Cook Inlet. The oil production facilities are out of range of ash flows from all but the largest eruptions, but flooding caused by ice and snow melting on upper slopes receiving volcanic ejecta is a recurrent problem. The impact of tsunamis generated outside of Cook Inlet Basin is low, but there is some potential danger from tsunamis produced by local volcanic debris avalanches reaching the shoreline. By comparison, the volcanic hazard in the QCB is relatively very small. Strong currents affect sediments on the floor of Cook Inlet. Pipeline failures in the early history of Cook

Inlet oil production have been attributed to erosion of sediment from below pipes. Preventive measures are now in place, including attachment of pipes to piles driven into the seafloor, anchoring of pipes in concrete, using heavy walled pipes, and regular side-scan sonar surveys to detect sediment motion. Coastal erosion is currently commonplace around Cook Inlet, as it is around the QCB, and set-back of facilities from coasts and river banks is required. Crossings of beaches subject to high erosion rates are allowed only with adequate reinforcement of infrastructure. Shallow gas deposits pose risks to structures founded on the seafloor above them. Some blow-outs have been caused by them.

Seismic Surveys

Since 1970, about 19,600 km of 2D seismic data, and 500 km^2 of 3D seismic data, have been acquired in Cook Inlet, and another 4000-5000 km may have been shot prior to 1970 (J. Cowan, Alaska Department of Natural Resources). The total is rather similar to the total seismic profile.

Oil Spills and Blow-Outs

Boyd and Shively (1999) quote oil spill statistics for Cook Inlet: During 1965-1980, 187 spills, with a total volume of about 7600 barrels, occurred. These were associated with production and transportation of crude oil. During this time there were 206 other spills (fishing vessels, product transportation vessels, others) with a total volume of 23,000 barrels. From 1987-1997, just over 5000 barrels were spilled in the Inlet, of which 96% was spilled in just one event. Oil spills in Cook Inlet from exploration and production during 1984-1994 totaled 250 barrels; there has never been a major oil spill (>1000 barrels) in Cook Inlet associated with this phase of activity. There has never been an oil blow-out in Cook Inlet, but there have been three gas blow-outs. Marine pipeline failures occurred in Cook Inlet during the 1960s and early 1970s. The failures were caused by sediment erosion, ice scour, corrosion, current-induced vibration, flange leaks and pipeline rubbing. There has been no reported seabed pipeline failure since 1976, though small leaks associated with marine pipelines continue. Very little oil has been spilled into the Inlet from shore facilities, with only a couple of incidents recorded in the 1990s. Two tanker oil spills have affected Cook Inlet. In 1987, oil—less than 3800 barrels—was spilled from the tanker Glacier Bay, en route to the Nikiski refinery. In 1989, the Exxon Valdez spilled 262,000 barrels in Prince William Sound, the major coastal inlet immediately east of Cook Inlet, and affected fisheries in Cook Inlet. Cook Inlet is the only estuary in the U.S. that receives discharge of drilling wastes; all other drilling and extraction activity in other U.S. estuaries operates under 'zero discharge' rules. Also, Cook Inlet platforms are exempt under a unique National Pollution Discharge Elimination System (NPDES) waiver. The 1996 estimates of the US Environmental Protection Agency (EPA) indicate that the oil and gas industry discharged more than 50 million barrels per year of oily water into Cook Inlet, which corresponds to more than 1700 barrels of crude oil per year. Dilution of this annual amount in the water volume of Cook Inlet yields a hydrocarbon content of 1 part in 2 billion. It is known that concentrations as low as 1 part in 1 billion of polycyclic and polyaromatic hydrocarbons (PAHs) can be toxic to fish embryos if exposure is chronic (Carls et al., 1999). While the average levels of concentrations of PAHs from discharged waters, once diluted in the total volume of Cook Inlet are below the levels for toxic impacts on embryos, there may be local transient concentrations that are toxic. The November 2003 Final Environmental Impact Statement for the Cook Inlet Planning Area (MMS 2003-056, Lois Epstein, Cook Inlet Keeper) indicates that for new development drilling or production the new EPA requirements still allow for discharge of deck drainage and sanitary wastes but no longer allows for the discharge of produced water or drilling muds and cuttings.

Protected Areas

The Cook Inlet area has four national parks, one national forest, one national estuarine reserve, two national wildlife refuges, four state parks and sanctuaries, and seven critical habitat areas (CIRCAC: *http://www.circac.org*). The total area protected is a significant fraction of land adjacent to the Inlet and includes several inshore marine zones. Protection in Cook Inlet is more advanced than it is in the QCB, though actual protection and proposals of protection for the QCB may involve a higher proportion of the marine area.

Impacts on Biota

The lower Cook Inlet is particularly rich in biota (Wagner et al., 1969). The upper Cook Inlet area is an important migration pathway for fish, en route to spawning grounds. Harvested fish include salmon, halibut, flounder, sole, and sculpins. Harvested shellfish include crab, shrimp, clams, scallops, oysters and abalone. The fisheries continue to be important to the economies of both Alaska (see http://www.cf.adfg.state.ak.lus/geninfo/about/budget/03overvw.pdf) as well as the entire British Columbia (see (http://www.agf.gov.bc.ca/fish_stats/pdf/BC_Fisheries_&_Aquaculture_Sector_s00s.pdf). The commercial harvest in Alaska has an annual landed 'exvessel' value of around $1.5 billion. Groundfish are responsible for over half this amount; salmon for about 20%. In Cook Inlet the salmon fishery is the most important and its landed value runs at about $40 million per year, which exceeds by a modest amount the total landed value of the commercial salmon fishery in BC (excluding aquaculture, which accounts for $260 million). It is of interest to note here that revenues of the recreational (sport) salmon fishing industry in both Alaska and BC, for each of freshwater and saltwater, exceeds that of the commercial salmon fishery by an order of magnitude. Taking salmon harvest as an indicator of the health of the commercial fishery in Cook Inlet, it is to be noted that annual totals climbed to highs in the late 1980s and have since dropped back to levels similar to those of the early 1960s. There are several reasons for variations in annual harvests in the fisheries, including management decisions on allowable catches, variations in prices, and stock levels. A successful salmon fishery continues to coexist alongside oil and gas development in Cook Inlet. Among marine mammals, beluga whales in Cook Inlet (Huntington, 2000) are now listed as candidates for protection under the U.S. Endangered Species Act. The impact of oil spills on reducing prey, with consequent reduction of beluga population, is considered uncertain.

Community Involvement

A striking feature of oil and gas activity in Cook Inlet is the participation of various stakeholder groups in monitoring and advising the industry and its regulators. Much of this resulted from the Exxon Valdez oil spill in 1989, in neighboring Prince William Sound. The resulting Oil Pollution Act of 1990 states that "only when local citizens are involved in the process will the trust develop that is necessary to change the present system from confrontation to consensus." Community involvement has been essential as a reaction to oil spills and other environmental problems caused by the oil and gas companies, even as recently as 1995. The Exxon Valdez oil spill occurred in March of 1989 in Prince William Sound, just to the east of Cook Inlet. A total of 262,000 barrels of crude oil spread along 1,300 miles of the south Alaska coastline. The *Exxon Valdez* Oil Spill Trustee Council was formed to oversee restoration of the injured ecosystem through the use of the US$900 million civil settlement. It funds a couple of groups in Cook Inlet (CIRCAC, CIIMMS). Although it has been 16 years since the spill, oil still remains in the impacted area. Intertidal and shallow subtidal habitats are still contaminated, some species have not recovered, and the productivity of the ecosystem as measured by salmon and herring fisheries have not returned to pre-spill level (see http://www.afsc.noaa.gov/abl/oilspill/oilspill.htm). The Auke Bay Laboratory is conducting research projects funded by the EVOSTC). During the first few years of remediation, there were quite different estimates of spill impact and biotic recovery by industry and independent observers (R. Greer, 2003). Partially funded by the EVOSTC, CIRCAC was set up in 1991 as a result of the Oil Spill Act of 1990. The mission of the Council is to "represent the citizens of Cook Inlet in promoting environmentally safe marine transportation and oil facility operations in Cook Inlet. This is accomplished by 1) monitoring and researching impacts of operations, 2) advising on regulations, 3) reviewing industry permits, regulations, and contingency plans for facilities and tankers, and 4) recommending changes to existing practices. By law, major companies in the Cook Inlet oil industry are required to provide annual funding for CIRCAC. Alaska's *Cooperatively Implemented Information Management and Monitoring System (CIIMMS: info.dec.state.ak.us/ciimms).* Another project funded by the EVOSTC, through the Alaska Department of Environmental Conservation and the Alaska Department of Natural Resources, the CIIMMS project provides the public with web-based sources of information on Alaska's natural resources. This information consists of a wide variety of accessible maps and databases focused on southern Alaska, and contributed by numerous groups. It will be expanded into a state wide information system within the next few years.

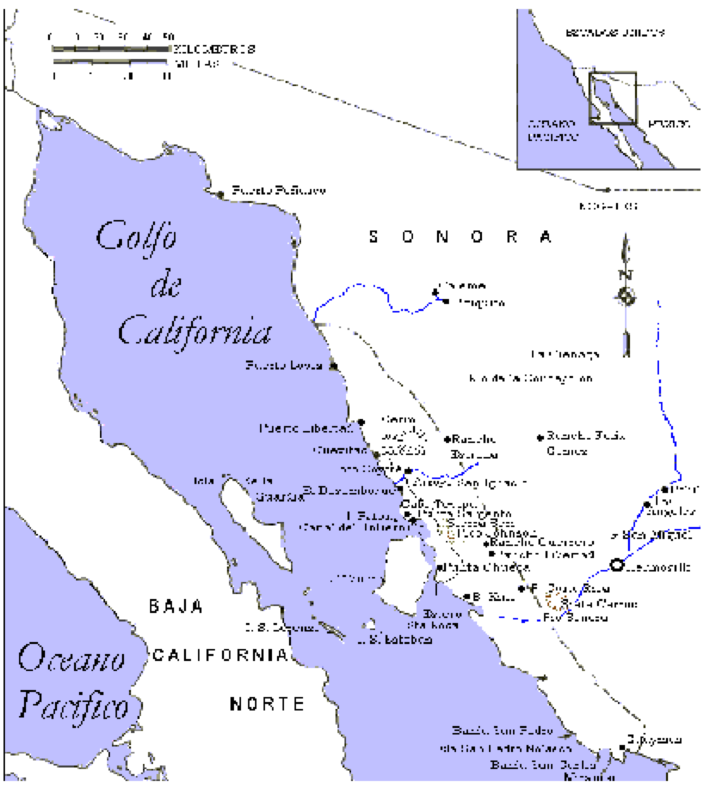
The Cook Inlet Keeper was set up by environmental organizations in 1995 with 3 years of start-up funds provided by oil companies (Unocal, Shell-Western and Marathon). This was done as part settlement of over 4000 permit violations during the previous five years, caused by discharge of grey and produced water into Cook Inlet. The EPA found the allegations so serious that it joined the litigation. The CIK provides citizen education and monitors the environmental health of watersheds around the Inlet with a particular focus on water quality in streams, lakes and estuaries.

Conclusions

Cook Inlet has a thriving commercial fishery, a very lucrative sport fishery, and a growing tourism industry (a million people visit Anchorage each year), all of which have coexisted for over 40 years with oil and gas activity that currently provides employment to around 1500 people locally, and contributes hundreds of millions of dollars annually into the Alaskan economy (AOGA, 2000). Coordination of citizen's groups with stakeholders in industry and government is of value in monitoring industry performance, and its plans for future development. Public education and environmental monitoring, together with readily available information sources are key to this process. Impacts of oil development on the environment are being mitigated by improved methods and technologies.

An important lesson from the Cook Inlet history is the value of an educated, informed citizenry. By coordination through multi-stakeholder groups, it undertakes monitoring of water quality and biota, to provide independent checks on industry performance and on general environmental quality, which is affected by many other processes both natural and anthropogenic. The acquisition of baseline data in assessing change is also underscored. The effectiveness of increasingly stringent regulation is also manifest in reducing spills and permitted releases of waste from offshore operations. The Cook Inlet oil industry is almost depleted but the associated gas industry will likely continue for several years.

The North American site with the third greatest tides (tidal range) is the Gulf of California located between the Baja Peninsula and mainland Mexico.



Marine Discovery focuses on marine biology and conservation of the Gulf of California, also known as the Sea of Cortez. The Gulf of California has some very special environments and many species of organisms found nowhere else on earth. Some interesting facts are listed below.

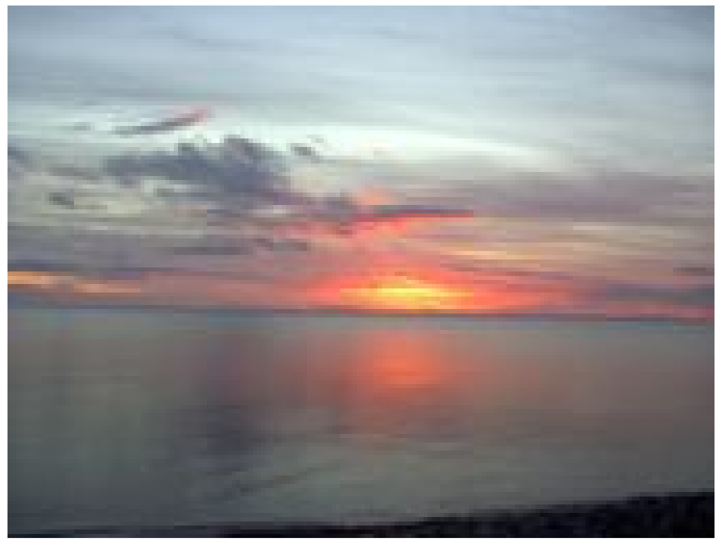
1. The Gulf of California is approximately 1,500 km long and 160 km wide. It has mixed semi-diurnal tides and one of the greatest tidal ranges on earth. The difference between the highest tide and lowest tide covers up to 2 miles horizontally and as much as 9 meters vertically in the northern gulf. The Gulf of California is one of the youngest ocean bodies, probably having
2. been formed by the separation of the North American Plate and the Pacific Plate by *plate tectonic movement*.
3. The Gulf of California is generally studied as two regions: the northern gulf and the southern gulf, with the border between the two near Guaymas. The northern portion of the gulf is shallow (up to 200 m deep) due to a large amount of siltation from Colorado River run-off. The northern gulf has many endemic species including populations of the vaquita (the endangered harbor porpoise) and the totoaba (a large endangered fish). Because the Colorado River once flowed into the Gulf, but now rarely does, many changes are occurring in the estuarine environment at the far northern end. The sedimentation and other changes in the environment brought on by the loss of the inflow from the Colorado River favor the isolation of species and their consequent speciation.
4. The Southern basin is much deeper, and includes the Guaymas trench, which is approximately 2000 m deep. The trench has volcanic and hydrothermal vents, which support biotic communities based on hydrogen sulfide for energy, rather than sunlight. Tidal ranges are not as great in the southern Gulf, making the northern basin better for studying the intertidal zone. The S. Gulf is similar to the marine environment south of the Gulf; many of the species seen in the Pacific Ocean have made their way into the Gulf of California.
5. Throughout the Gulf, winds and tidal action cause upwelling. The large amount of sunlight, combined with the nutrients provided by upwelling, allow high primary productivity throughout the Gulf. The high primary productivity supports numerous invertebrates, fish and large marine mammals, including the awesome fin whale! Pods of dolphins and orcas are seen regularly, and the migration of elephant seals into the Gulf of California is currently being studied. Ed Ricketts (*Between the Tides*), John Steinbeck (*Log from the Sea of Cortez*), Richard Brusca (*Common Intertidal Invertebrates of the Northern Gulf of California*) and Donald A. Thomson (*Reef Fishes of the Sea of Cortez*) are just a few of the people who have written about the richness and diversity of the Sea of Cortez.

South American sites with the greatest tides (tidal range) are located in Chile and Argentina. The Magellan Strait in Chile is home to Bahia Posesión, Banco Dirección, and Dungeness where very high tides exist.

Satellite View of Magellan Strait, Chile

Magellan Strait, Chile

The **Strait of Magellan** is a navigable route immediately south of mainland Chile, South America. The strait is arguably the most important natural passage between the Pacific and the Atlantic oceans, but it is considered a difficult route to navigate because of the inhospitable climate and the narrowness of the passage. Until the Panama Canal was finished in 1914, the Strait of Magellan was often the only safe way to move between the Atlantic and Pacific Oceans. Protected by the Tierra del Fuego to the south and the bulk of South America to the north, ships crossed with relative ease, removed from the dangers of Drake Passage. The Drake Passage is the relatively narrow stretch of ocean separating Cape Horn (the southern tip of South America) from Antarctica, the waters of which are notoriously turbulent, unpredictable, and frequented by icebergs and sea ice. Until the Panama Canal was finished, the strait was the second-most used route for ships crossing between the Atlantic and the Pacific oceans.

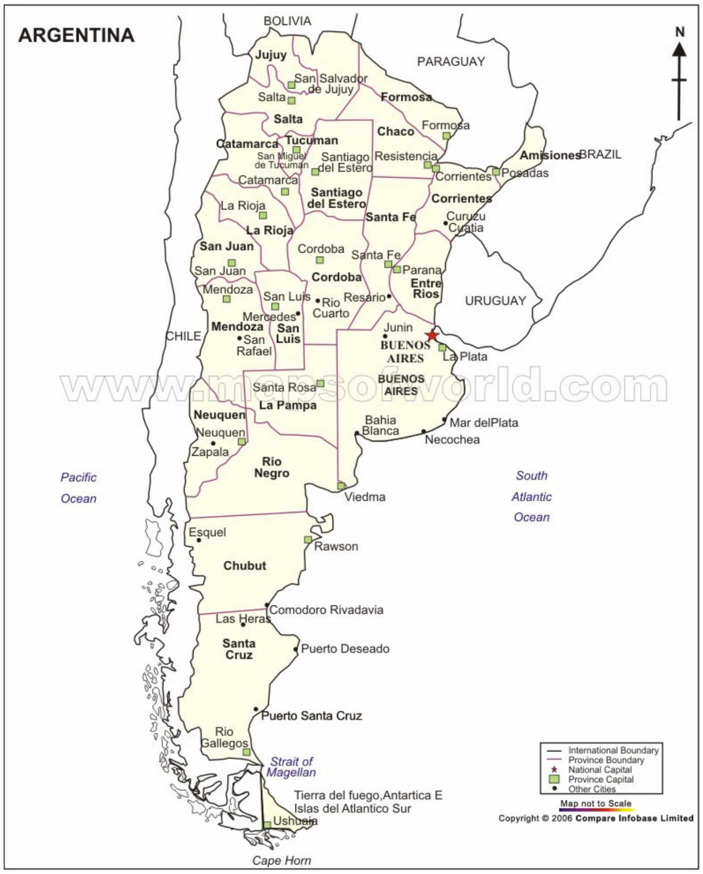


Strait of Magellan at Dawn

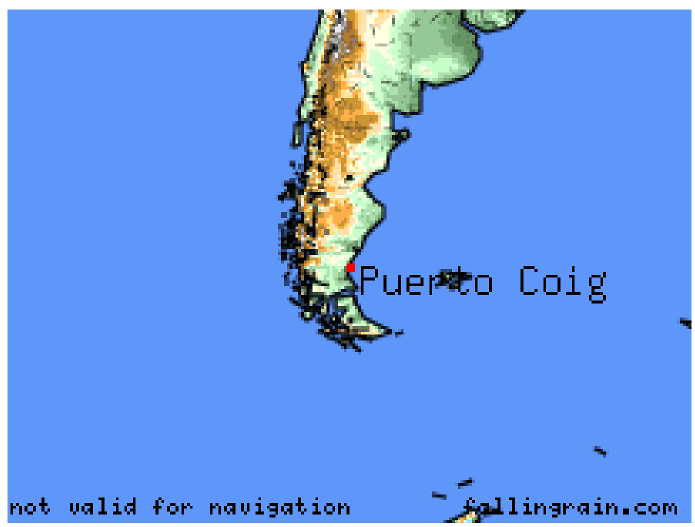
Ferdinand Magellan became the first European to navigate the strait in 1520, during his global circumnavigation voyage. Because Magellan's ships entered it on November 1, it was originally named **Estreito de Todos los Santos** (Strait of All Saints).

On May 23, 1843 Chile took possession of the channel, under whose sovereignty it remains as of 2006. On the coast of the Strait lies the city of Punta Arenas and the village of Porvenir. This path was crossed by early explorers, including Ferdinand Magellan, Francis Drake, Charles Darwin, among others. Prospectors during the 1849 California gold rush used this route as well.

The Argentinian sites with the greatest tides (tidal range) are located at Rio Gallegos, Ria Coig, Santa Cruz (Punta Quilla), Punta Loyola, Cabo Virgenes.



Capital of the Province of Santa Cruz, **Río Gallegos** is the continental city farthest south in Argentina. The total surface of the country is 3.761.274 km^2, while the province of Santa Cruz has a surface of 243.943 km^2, and is inhabited by 159,839 people which translates into an average of 0.7 inhabitants per square kilometer. Today Río Gallegos is a city of more than 80,000 inhabitants, head of the department of Güer Aike, second most important city in the patagonian coast, with an international airport, banks, hotels, restaurants,etc. Río Gallegos is in the immensity of the patagonian plateau, crossed by river valleys in a west-east direction. The city is precisely on the steps descending to the Argentine sea at a latitude of 51º 38' south and a longitude of 69º 12' west. It is a centenary city on a low wetland, only 20 m above sea level, 2,636 km from the City of Buenos Aires and located on the Gallegos River, the most austral river in continental Argentina. This river is born in the confluence of the rivers Penitente and Rubens, in Chile, and is a typical patagonian river, middle size, with banks alternating beaches, and cliffs, with calm waters as well as rapid currents, mainly in its upper part where it presents many curves, stony grounds and deep pools. In these latitudes, the weather is severe in winter and the sun only warms for three or four hours a day, while in summer it is present up to half past ten in the evening. Río Gallegos city has become a distribution centre for tourists who visit southern Patagonia. It has a dry cold weather with temperatures around -15ºC, strong winds in spring, and up to 25ºC in summer. At present these farms are devoted to extensive sheep breeding. The port of Rio Gallegos is opposite the capital, 8 miles from its outlet, and one of the most important ones in Patagonia. It presents the problem of tidal amplitude (17 to 20 m.), and so ships have to wait for long periods in Punta Loyola to the south of the outlet before they can anchor. It has a commercial pier and a timber pier. It is a fishing port, and they export ovine frozen meat, wool and leather, as well as coal from the mines in Río Turbio. Its international airport is the base for aerial operations to Antarctica and also a stopover for the jumbo jets of Aerolíneas Argentinas that perform the transpolar flight to New Zealand and Australia.



Puerto Coig - Site of Argentina's Greatest Tides

Ria Coig, Santa Cruz (Punta Quilla), and Cabo Vírgenes communities are all located nearby.

The very large Bay of Fundy will permit the installation of about 800 Dolphin™ Offshore Integrated Power Tidal Generators. The much larger adjacent Gulf of Maine will support thousands more at a slightly less power generation efficiency because of smaller tidal ranges. The much smaller Cook Inlet will permit about 300 Tidal Generators. Canada requires about 150 Tidal Generators for its total electricity independence whereas the United States requires about 1000 for its total electricity independence. The total tidal generators required for Canada's and the

United States' total electricity independence numbers up to 1,150, slightly more than the combined capacities of the-Bay of Fundy and the Cook Inlet. The deficiency can easily be made up by the Gulf of Maine with significant room to spare.

The Construction site for the Bay of Fundy Tidal Generators will be along its coast. The units will be constructed within dry docks below high tide and behind large flood gates. Upwards of 10 tidal generators will be constructed simultaneously. The construction period takes about 3 months to produce 10 tidal generators. After construction is completed the flood gates will be opened at high tide to permit the completed units to be tug barge towed to their final destination in the same manner as offshore crude oil production rigs are built onshore and then floated to their final destination. Several dry docks will be built to provide for added production capabilities.

In support of tidal generator construction barge load quantities of limestone will be transported to the construction site and made into Portland Cement. The limestone will likely come from Florida. Portland Cement manufacture will be accomplished within an enclosed building to prevent discharge of carbon dioxide and other greenhouse gases (GHG) to the environment. The carbon dioxide gas will be fed into a photobioreactor to grow microalgae through photosynthesis. The microalgae, in turn, will be converted into biodiesel fuel. The biodiesel fuel will provide some of the required energy required for cement manufacture.

The material of construction for the Tidal Generators will be concrete. Concrete consists of cement, aggregates, and water. The cement will be produced locally and some of the required aggregates will obtained from the Bay of Fundy itself. If the USEPA would lift its restriction on the movement of slightly radio active phosphogypsum stacks (gypstacks) from the Florida and Louisiana phosphate fertilizer production sites gypstacks could be made to disappear over time. The Florida Institute of Phosphate Research (FIPR) has already established that the gypstacks are suitable aggregate material for concrete products.

The construction site for the Cook Inlet Tidal Generators will also be along its coast within dry docks below high tides—same as Fundy. The limestone will come from the Vancouver area (Powell River) and transported to destination where it will be made into cement. Most of the aggregates will come from Cook Inlet itself. The left over drilling muds from the petroleum industry may well be suitable as aggregate materials.

The construction site for the Gulf of California Tidal Generators will also be along its coast within dry docks below high tides – same as Fundy. The limestone will come from the Vancouver area (Powell River) and transported to destination where it will be made into cement. Most of the aggregates will come from the Gulf of California itself.

The construction site for the Strait of Magellan Tidal Generators will also be along its coast within dry docks below high tides – same as Fundy. The limestone will come from Florida and transported to destination where it will be made into cement. Most of the aggregates will come from the Strait of Magellan itself.

The construction site for Argentina's Tidal Generators will also be along its coast within dry docks below high tides – same as Fundy. The limestone will come from Florida and transported to destination where it will be made into cement. Most of the aggregates will come from the Puerto Coig area.

The tidal generators will be manufactured by WaterSmart Environmental under a private label arrangement. They will be marketed as a build-own-operate product to Canada and the United States in the same manner as the company is marketing its waste-to-energy technologies throughout the world. In so doing, the company will become an Independent Power Producer (IPP) when it becomes so qualified.

The company also intends to market the tidal generator product to other countries throughout the world on a fully installed basis. The manufacturing raw cost of a single 500 MW Dolphin™ Integrated Power Tidal Generator is estimated at $200 million installed. The marketplace cost of an operating 500 MW dirty coal fired power plant is about $800 million. A clean coal fired power plant costs about twice as much. The profit margin of the Tidal Generator appears to be quite favorable. Many countries are in need of additional power, especially India and China. India has favorable sites for their installation. China sites have yet to be researched. The production of Tidal Generators in other countries is anticipated.

The coal fired power plant business in both Canada and the United States is strongly protected (politically) and subsidized (by their respective departments of energy) by their respective governments. This fact presents a sizeable marketplace barrier to the product's implementation in the marketplace. The government's protection is far less in the United States because of the many mayors and governors that now support climate change renewable energy Initiatives. The tidal generators are 100% renewable and 100% compliant with Kyoto Protocol. The environmentalists will express significant interest in the technology and will quickly determine that the product cannot harm the pink snail, the beluga whale, or anything in between.

Canada, meanwhile, is trying to cope with diminishing production from its Oil Sands Industry (Alberta Province) due to natural gas shortages and its increased marketplace price (the always consistent law of supply and demand). In addition to its diminishing production, the Oil Sands industry has built up a pile of polluted liquid and solids that are discharging massive amounts of carbon dioxide and methane gas to the environment not to mention the significant discharges of carbon dioxide from its everyday operations. Perhaps they will listen to WaterSmart's waste-to-energy existing proposal to increase crude oil production, perhaps combined with the Tidal Generator product. One thing for sure, the inherent marketplace barriers will have to be removed before tidal generator production can begin. The marketplace impact of the technology will drive retail electricity prices lower and lower to perhaps two thirds (2/3) as much as they are today throughout Canada and the United States. It is this politically favorable driving force that will ultimately guarantee the success of the product itself. Politicians that say **no** can be voted out of office.

The Chemists, Power Engineers, Environmentalists, Constructors, Builders, Scientists, and Senior Management at ***WaterSmart Environmental, Inc.*** welcome your inquiries with enthusiasm.

From the Engineering Department of

WaterSmart

Environmental, Inc.