Managing Tidal Change

Final Project Report March 2008

Bay of Fundy Canada
Severn Estuary UK
Penzhinskaya Guba Russia

Natasha Barker

Winston Churchill Memorial Trust
Travelling Fellowship Award 2006

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Preface

High tidal range visible at Woodspring Bay on the Severn Estuary.

The Winston Churchill Memorial Trust provides Fellows with a unique opportunity to meet people from different countries with similar interests. Fellows gain knowledge and experience of significant value to the country, the community, their occupation and their personal development. The Trust view the Fellowship Award as an 'opportunity of a liftetime,' providing the resources to enable travel to countries of relevance to the Fellows work.

This project looked at three estuaries with the highest tidal ranges in the world, to compare their physical characteristics with human use and management. In particular the potential impacts of climate change, predicted sea level rise, storms and tidal surges are likely to have a significant affect on these dynamic estuaries and people's lives.

The Bay of Fundy in Canada experiences the highest tidal range in the world. The Severn Estuary in the UK experiences the 2nd highest tidal range in the world after the Bay of Fundy.

The Penzhinskaya Guba experiences the highest tidal range in Russia, of a similar range to the Severn Estuary in the UK.

Three objectives were identified as the focus for the research across the three estuaries:

i) Public awareness and marketing the tide for tourism;

ii) Land use management and flood risk planning;

iii) Renewable energy options.

The difference in population, with less than 0.1% around Penzhinskaya and 10% around Fundy compared to the Severn, was found to be an important influence on how people recognise the tide, live with the tide and harness the tide.

Many recommendations for the authors work with the Severn Estuary Partnership resulted from the visit to the Bay of Fundy. Government, industry and non-governmental organisations in the UK have taken an active interest in the research results. Progress in Canada with legislation and policy for marine and coastal planning, provided useful experience for development of the English Coastal Partnerships Working Group and input to proposals for a UK Marine Bill. Collaboration between professionals working on tidal energy options has been facilitated through this research.

Visiting the University of Alaska Fairbanks to meet scientists who had researched tides in the Sea of Okhotsk informed the visit to Far East Russia. The remote Penzhinskaya Guba estuary provided a significant contrast to the highly developed Severn Estuary and Bay of Fundy. As a result of witnessing an untamed tide in a wilderness environment, observations were made on the sustainable development and management of estuaries 'in the west'. It highlights that for the Severn Estuary Partnership it would be useful to have a better understanding of the 'original' baseline environment and natural processes. This would inform future flood risk management, shoreline planning and feasibility studies for tidal energy.

Two reports were produced following visits to the Bay of Fundy in 2006 and Penzhinskaya Guba in 2007. This final report summarises the key findings from the research and field visits.

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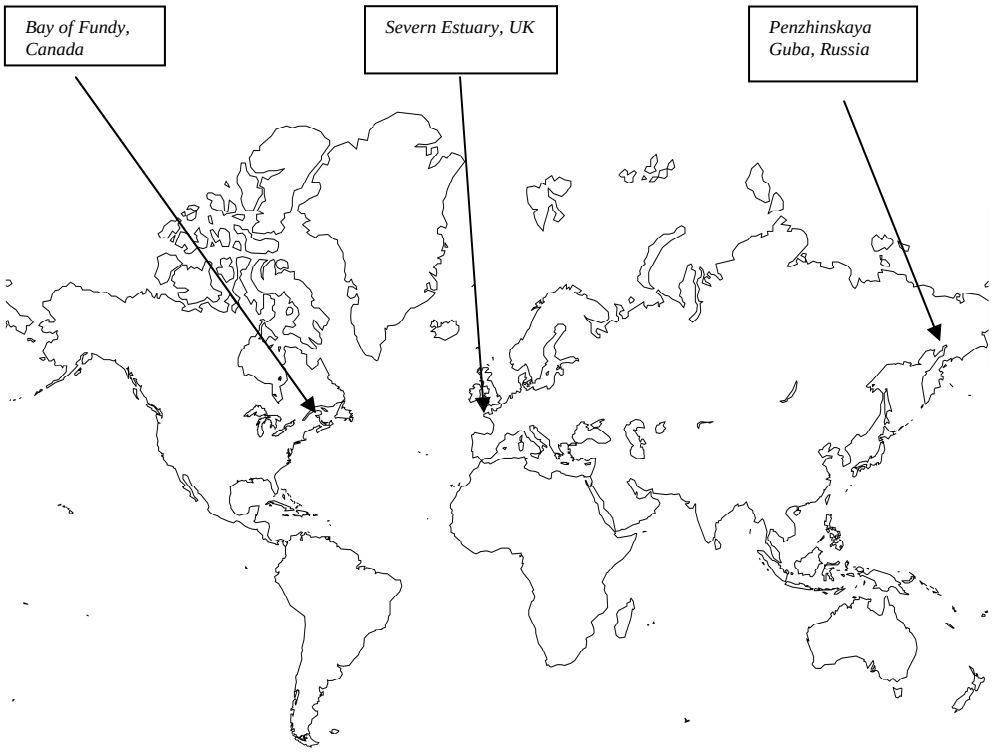

Three estuaries in the world with some of the highest tidal ranges.

> ***"There is no drop of water in the ocean, not even in the deepest parts of the abyss, that does not know and respond to the mysterious forces that create the tide."***
>
> **Jim Lynch in'The Highest Tide'.**

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1 Introduction

1.1 Aims of the Fellowship

Second Severn Crossing spanning England & Wales, opened 1996.

The aim of this project was to investigate man and nature's response to tidal change on estuaries with the highest tidal ranges in the world. The potential impacts of climate change; predicted sea level rise, storms and tidal surges may have the greatest affect on these areas. It is considered that the challenges for coastal management from the way people live with their environment are seen to be most evident and challenging in these dynamic high tidal coastal areas.

Natasha Barker from the Severn Estuary Partnership based at Cardiff University in UK, has been an Estuary Officer since 1998. This Churchill Fellowship enabled Natasha to compare current approaches to coastal management around the Severn Estuary spanning England & Wales in the UK (14m tides[1]) alongside two other coastlines experiencing some of the highest tidal ranges in the world; the Bay of Fundy, Nova Scotia & New Brunswick in Canada (16m tides[1]); and the Penzhinskaya Guba in the Sea of Okhotsk, Russia (13m tides[1]). The 3 sites for investigation contain some of the highest tidal ranges in the world.

The fellowship aims were fulfilled through two phases of travel during the summers of 2006 and 2007. The rationale for using these 3 sites for investigation was based on their high tidal ranges and the following specific aims:

- **Phase 1: Canada and Alaska** - compare existing approaches to coastal management between the UK and Canada, through sharing experience between the Severn Estuary and the Bay of Fundy. As part of the phase 1 trip, preparations for Phase 2 were explored with scientists in Alaska who had researched tides in the Sea of Okhotsk.

- **Phase 2: Russia** - consider the interaction between people and the tides, by comparing the extremes of the Severn Estuary, a highly developed area, with the Penzhinskaya Guba, a remote and almost entirely undeveloped area. (The Bay of Fundy lies somewhere between these two extremes.) The Penzhinskaya Guba presents an opportunity to experience a 'control' site where there is very little influence of human development on the shoreline.

Information from the 3 estuaries would be used to compare the physical character, geographical knowledge and management approaches to address 3 current issues, as described in the objectives below.

1.2 Objectives

The overall objective of the project was to compare approaches to managing tidal change and establish links with organisations managing and/or researching the influence of the tide.

Current issues relating to management of the Severn Estuary led to three specific objectives for the research:

[1] Approximate highest tidal ranges. The highest recorded tidal range in the world is 16.27m measured at Burntcoat Head in the Minas Basin in the Bay of Fundy, Canada.

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i) Public awareness and marketing the tide for tourism: 'Recognising the Tide'.

Assess the level of community awareness of high tidal ranges. Explore existing and potential opportunities for promoting public awareness of the coastal environment (and climate change impacts) through marketing and tourism initiatives. Gather examples of interpretation methods and public involvement in tide-related activities (e.g. tidal bores). Compare management approaches to habitat protection for migrating birds, human impacts and response.

ii) Land use management in response to flood risk: '**Living and Working with the Tide'**

Assess the extent of coastal protection and flood defence measures and future options. Due to climate change there is increasing pressure on inter-tidal habitats with sea level rise and the risk of habitat and species loss due to coastal squeeze[2]. Compare habitat and landscape change in environments with high and low population densities. How adaptive are approaches to shoreline management and development plans?

iii) **Opportunities for renewable energy**: **'Harnessing the Tide'**

Identify past, present and proposed options for harnessing tidal energy. Also due to climate change, there is increasing political attention towards opportunities for renewable energy. Tidal power plants could provide a useful source of energy, but technologies are relatively young. Make links with academic, government and commercial organisations involved in assessing the potential for renewable energy using tides.

1.3 Itinerary

The travelling fellowship was spent on field visits and linking with organisations responsible for resource management and research interested in one or more of the above issues. The full itineraries are provided in the appendices.

COUNTRY	PLACES	ORGANISATIONS VISITED	DATES
PHASE 1: 2006			
Canada	***Bay of Fundy:*** *Nova Scotia & New Brunswick:* Dartmouth & Halifax - based at the Bedford Institute of Oceanography. Truro, Wolfville, Parrsboro, Moncton.	Bedford Institute of Oceanography, Dartmouth. Minas Basin Working Group, Wolfville. Bay of Fundy Tourism Partnership, Parrsboro. Nova Scotia Agriculture & Resource Stewardship, Truro. St. Mary's University Geography Dept, Halifax. Annapolis Royal tidal power station, Annapolis Royal. Clean Annapolis River Project, Annapolis Royal. Environment Canada, Dartmouth. Acadia Centre for Estuarine Research, Wolfville. Fundy National Park, New Brunswick.	20th July – 9th August 2006
Alaska	Fairbanks	Institute of Marine Science & International Arctic Research Centre, University of Alaska Fairbanks.	10th - 14th August 2006.
PHASE 2: 2007			
Russia	Moscow	World Wide Fund for Nature, Russia	5th July 2007
	Penzhinskaya Guba *Shelikova Bay & the Sea of Okhotsk:* Yelisovo, Petropavlovsk-Kamchatskiy, Korf & Tilichiki, Kamenskoye & Manily.	Pacific Institute of Geography – Kamchatka Branch. World Wide Fund for Nature – Kamchatka Branch. Kamchatka Oblast & Koryak Autonomous Okrug – regional and local authorities. Penzhino District Administration.	9th July – 9th August 2007

[2] Coastal squeeze is caused by increasing sea levels meeting coastal defences which don't allow inter-tidal habitats to migrate inland, resulting in a loss of inter-tidal area.

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2 Tidal Change

2.1 The Project

> ***"Unusual travel suggestions are dancing lessons from God"***
>
> Kurt Vonnegut, *Cat's Cradle.*
> Quoted in the introduction to
> Jon Turks book
> 'In the Wake of the Jomon – Stone Age Mariners and a Voyage Across the Pacific'
> (2005).

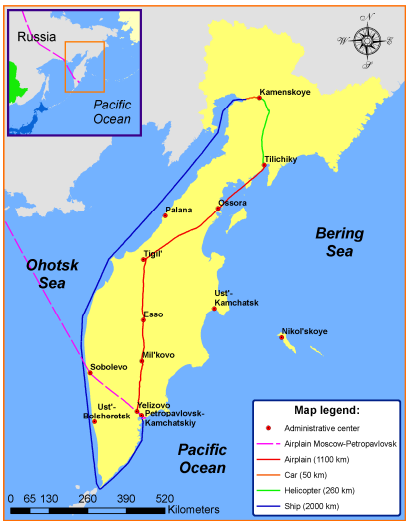
Creating this project was the beginning of an intellectual and personal challenge: bringing together the author's professional experience as an Estuary Officer in the UK, with a personal interest in Russia.

From a professional perspective, the fellowship award coincided with working for the Severn Estuary Partnership[3]. This voluntary organisation brings together all those that plan and manage the estuary and its resources to work towards sustainable development. Planners around the Severn Estuary are facing big questions about the future use and management of resources, trying to find a path for sustainable development and exploring the best balance between people and the environment. It was natural to be curious about our 'big brother' the Bay of Fundy in Canada, which experiences an even higher tidal range.

People are warned to keep away from the Severn Estuary.

The rationale for this project was based on the following current issues in the Severn Estuary:

- Due to the dynamic, sometimes dangerous nature of the tides, children are warned to keep away from the estuary and many people are not aware of its value to society. The concentration of population in urban areas has detached people from the tide.
- As a result of climate change and sea level rise, we face huge challenges over how and whether to protect low lying land which has been reclaimed from estuaries and coastal areas. Around 80% of the Severn Estuary shoreline has been modified with coastal defences protecting some 3 million people and properties from flooding.
- The Severn Estuary is under the spotlight over how to exploit its tidal energy potential. Development decisions could have a critical impact on the future health of the natural ecosystem, but could help to meet a significant proportion of Britain's renewable energy target and help to improve security of energy supply for the UK.



Route of Travel to Penzhinskaya Guba, Far East Russia.

The Severn Estuary Partnership aims to raise awareness of the value of the estuary and promote sustainable management of its resources. As the leader of this partnership initiative, the fellowship offered the author opportunity to make contact with other professionals to explore different approaches to shared issues.

From a personal perspective, the fellowship presented an opportunity to visit a remote estuary in Russia which offered a different perspective on people's relationship with the environment. A virtually unpopulated estuary could further my understanding of how a natural estuarine ecosystem would look - a baseline environment from which to consider the challenges posed by sustainable development in the west.

The project provided the opportunity for unique research. Reaching Penzhinskaya Guba in such a remote location was a journey of a lifetime in itself. A description of this aspect of the fellowship is provided in the appendices.

[3] See www.severnestuary.net/sep

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2.2 Connections with Churchill

The perception of Britain as a colonial and war-winning nation maybe less prominent since Churchill's days, but his perceptions of relations between Europe and Russia are as relevant and interesting today.

Steepholm Island in the Severn Estuary.

> ***What they desire is …indefinite expansion of their power and doctrines. [We must reach]… a good understanding on all points with Russia …and by the maintenance of that good understanding through the many peaceful years… supported by the whole strength of the English-speaking world and all its connections.***
> Winston Churchill in his 'Sinews of Peace' speech, March 1946, Missouri U.S.

In what became commonly known as Winston Churchill's *Iron Curtain Speech* (which he gave in the United States after the end of the second world war) he warned of the raising of the iron curtain across Europe. Churchill foresaw the new division between Europe and cautioned against the Russian super-power. Relations between the UK, North America and Canada have remained strong. Now we are at the other end of the cold-war and Europe is uniting with the inclusion of former Soviet Union countries into the European Union, we have entered a new era of political relations between east and west. Russia may have 'shrunk' in size but is strengthening its position within the world economy. It is a land of vast natural resource potential and hardy people. Uniting three continents in a study of estuaries offered an opportunity to increase cultural understanding as advocated by Winston Churchill. Further observations on this perspective are provided in the conclusion and post project notes in the appendices.

2.3 Water Workers

> ***'Water Workers – river authorities, flood defences, coastal protection'***
> 2006 Winston Churchill Memorial Trust fellowship category

This fellowship award was given under the 'water workers' category in 2006. Water, like oil and other significant natural resources, is an essential component of life. Relations between countries over the use of natural resources are likely to increase in future decades. There is a need to ensure we are able to communicate and understand each other to share natural resources equitably and peacefully – using them at sustainable rates which do not damage the quality of the environment which we rely on for future human health. The impacts of climate change are likely to exacerbate competition for these precious resources.

River and coastal shorelines are often the focus of development due to their access to trade routes, the proximity of flatter and fertile land, with scenic landscapes and good recreational opportunities. The higher population concentration and intensive development of shoreline areas often threatens some of the most fragile natural habitats. Shorelines therefore present some of the biggest challenges for managing the balance between man and nature if we are to achieve sustainable development. Where tidal ranges are at their highest, it follows that this challenge is more pronounced.

Natasha, Severn Estuary Partnership Officer, near the 2nd Severn Crossing.

This report presents the findings of the fellowship in terms of nature's response to tides (section 3), man's response to the tides (section 4) and collectively how man and nature have responded by managing tidal change (section 5). It concludes with observations on how this project contributes to estuary management and our approach to pursuing sustainability.

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3 Nature's Response to Tidal Change

3.1 Introduction: Highest Tides in the World

Bay of Fundy, Canada.

Estuaries are created where rivers meet the sea. Nature's response to the rise and fall of tides is the formation of coastal habitats such as salt marsh and mudflats, which in biological terms are as rich as the rainforest. Where there is a high tidal range it naturally follows that the extent of the inter-tidal area is very wide and physical coastal processes very dynamic.

The highest recorded ***tidal range***[4] in the world is widely known to exist in the **Bay of Fundy, Canada** with the highest recorded tidal range of 16.27m measured at Burntcoat Head in the Minas Basin. The high tides have been attributed to the funnel shape of the Bay and the fact that the natural period of the Gulf of Maine-Bay of Fundy system exacerbates the tide height (the 'bath-water' effect). However, research conducted by the Canadian Dept of Fisheries & Oceans demonstrated that the tidal range in the Bay of Fundy is approximately equal to that of Ungava Bay in Canada (O'Reilly et.al, in Environment Canada (2005b).

Severn Estuary, UK.

The **Severn Estuary** is commonly known to experience the second highest tides in the world, after the Bay of Fundy in Canada. 14.7m is the maximum recorded tidal range at Avonmouth near Bristol.

One of the world's highest tidal ranges has been identified in the **Penzhinskaya Guba** (Bay) in the Sea of Okhotsk in Kamchatka, Far East Russia. Tide tables indicate the irregular diurnal nature of the tides and *Kowalik, Z. 2004* from the Institute of Alaska, Fairbanks, documents a 13.9m tidal range making this the highest tidal range site in Russia (Isachev, 2006).

Penzhinskaya Guba, Russia.

Other high tidal ranges are experienced in the White Sea in Russia, the Cook Inlet in the Gulf of Alaska, the Persian Gulf, the Java Sea, the west coast of New Guinea and off northern Australia and Antarctica. Within Europe, St. Malo on the La Rance river in France, claims some of the highest tides in Europe with an average range of over 12m.

A phenomenon of the tides that was considered worthy of further investigation were ***tidal bores***[4]. They are caused by the speed of the incoming tide relative to the downstream flow of the river. The existence of tidal bores in the Severn Estuary and in the Bay of Fundy is valuable to assessing public awareness and marketing tidal sites for tourism. In addition to the Severn Estuary and Bay of Fundy area, they are known to occur in other parts of the world, including on the River Amazon in south America and the River Quiantang in China.

Severn Tidal Bore.

3.2 Severn Estuary, UK

The Severn is Britain's longest river at 354km (220 miles) and largest coastal-plain estuary with an area of 557km^2 including an intertidal area of 100km^2. The tidal section of the river between Gloucester (upstream) and Weston-Super-Mare (downstream) is approximately 115km (90 miles) long and 15km (10 miles) wide at its mouth. The estuary spans England and Wales from the city of Gloucester in England to the urban

[4] See the Appendices for a definition of tidal range and tidal bore.

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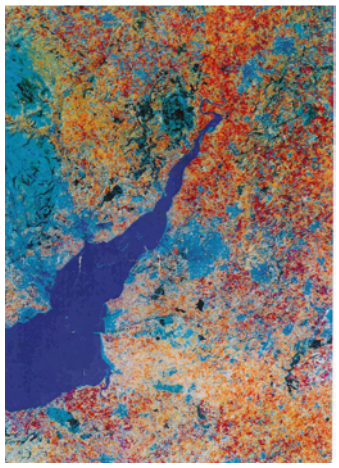
areas of Newport & Cardiff in Wales and Weston-Super-Mare and Minehead in South-West England. When its seaward extension, the Bristol Channel (80km wide between Devon & Pembrokeshire) is included, the inter-tidal habitat of mudflats, sand banks, rocky platforms, islands and saltmarsh is one of the largest and most important in Britain, occupying an area of around 2000 km^2. The Severn Estuary has recorded the 2nd highest tidal range in the world, on occasions in excess of 14.5m. The Severn Bore, a tidal wave which may reach 2m in height forms in the lower reaches of the River Severn during high spring tides and can travel up to 25 miles upstream as far as Gloucester. The extremely high tidal range and funnel shape of the coast make the Severn Estuary unique in Britain and rare on a wider European scale.



Satellite image of the Severn Estuary.

3.3 Bay of Fundy, Canada

The Bay of Fundy is part of the Gulf of Maine which lies between south-eastern Canada and north-eastern U.S.A. The Bay lies between Nova Scotia and New Brunswick, on the East Coast of Canada.

The Bay encompasses 2745km of salt water coast. Each day 100 billion tons of water flow in and out of the Bay of Fundy during one tide cycle, which is said to be equivalent to more than the combined flow of the worlds' freshwater rivers. The Bay is 270km long, straight-sided and funnel-shaped (like the Severn Estuary) with an 80km wide mouth and a head which is split into two narrow bays; Chignecto Bay and the Minas Basin. The Minas Basin experiences the highest tides at the upper end of the Bay of Fundy because earth rotates counter-clockwise in the northern hemisphere. The highest tides in the world with a 16.27m tidal range were recorded at Burntcoat Head in the Minas Basin. The primary cause of the immense tides is the resonance of the Bay of Fundy-Gulf of Maine system which is effectively bounded at the outer end by the edge of the continental shelf with its approximately 40:1 increase in depth. The Bay's tides cause large tidal bores, rapids and whirlpools where the incoming tide pushes its way upstream against the outgoing flow of the rivers St. Croix, Meander, Shubenacadie and Salmon.

Satellite picture of the Bay of Fundy.

> ***'A system with a biological pump at both ends'***
> Graham Daborn, Acadia University, Wolfville, Nova Scotia, Canada

Red sandstone cliffs and salt marsh dominate the shoreline. During extreme low water, the area of the exposed intertidal zone is approximately 400 km^2, or more than one-third of the total area of the Basin. No other coastal marine area in the world of comparable size has such a large proportion of bottom exposed to the air at low tide [Bousfield, 1959].

3.4 Penzhinskaya Guba, Russia

Russian Map of the Upper Penzhinskaya Guba.

Some of the highest tides in the world have been recorded in the Sea of Okhotsk in far north-east Russia. A tidal range of 13.9m has been reported, making this the highest tidal range site in Russia. The Guba (Bay/Estuary) is situated between the Magadan and Kamchatka regions of Far East Russia and flows into the Sea of Okhotsk. As with the tides in the Bay of Fundy and Severn Estuary, amplification of the tide occurs from Shelikova Bay at the mouth to the head of this funnel-shaped estuary. The extent of Penzhinskaya Guba from Shelikova Bay to the head of the estuary is some 400km long and 100km wide. In a similar form to the Bay of Fundy, the head of the Penzhinskaya Guba is split into two narrow bays between the mouth of the River Penzhino and River

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Low tide at Lydney Harbour on the Severn Estuary.

Low tide at Scots Bay on the Bay of Fundy.

Re-fuelling depot near Manily, Penzhinskaya Guba.

Talovka. Characteristics of tides in the Sea of Okhotsk have been investigated by scientists at the Institute of Marine Science at the University of Fairbanks in Alaska, U.S.A.

Tidal influence from the Sea of Okhotsk extends into the Penzhinskaya Guba and River Penzhino 50km upstream of the village of Manily at the mouth of the estuary. The tidal range is similar to the Severn Estuary but there is much variation in the height of the tides with an unusual irregular diurnal pattern (e.g. one or two high tides per day) as opposed to regular semi-diurnal tides in the Severn Estuary (e.g. two high tides per day). The climatic extremes in the Penzhino area, from -50^0c in mid-winter up to $+40^0$c in the summer, with some 220 days of winter with average temperatures of -6.5^0c (Bernshtein, 1996), mean that the shoreline is subjected to faster rates of erosion and accretion. Ice can form up to 4m thick. The presence of a tidal bore was not known by local fishermen, barge operators or hunters to exist on the River Penzhino. Fewer people have knowledge of the River Talovka so there is a possibility of a tidal bore in other tributaries feeding into the Penzhinskaya Guba.

The natural environment is in a pristine state compared to the Severn Estuary and Bay of Fundy. Indicators of the health of the ecosystem include references made by local people and scientists to over one million migratory birds (Yuri Gerasimov *pers.comm.*) and 500 beluga whales. The vast landscape of mudflats, salt-marsh and cliff shoreline are little explored with a low and decreasing population contained in a few settlements.

3.5 Physical Characteristics of the Three Sites

The Severn Estuary is similar in size and scale to one of the two arms of the Bay of Fundy: Chignecto Bay or the Minas Basin. The Penzhinskaya Guba has a similar form to the Bay of Fundy, with two major rivers. The table compares the main physical characteristics of the three sites.

Characteristic	Severn Estuary, UK	Bay of Fundy, Canada	Penzhinskaya Guba, Russia
Size of estuary/bay and intertidal exposure	557km^2 (intertidal area 100km^2).	Approx 1200 km^2 (intertidal area 400 km^2).	Approx 28000km^2 (upper estuary intertidal area approx 600km^2).
Largest dimensions (approximate)	Bristol Channel – approx 170km long & 70km wide. Estuary - 50km long, 15km wide.	Bay – 270km long, 80km wide Minas Basin - 80km long and 30km wide.	Guba – 400km long, 100km wide Upper estuary 50km long, 12km wide.
Highest tidal range	14.7m at Avonmouth.	16.27m at Burntcoat Head (Minas Basin).	13.9m at Cape Astronomechski
Average high tidal range	Approx 12m.	Approx 14 m.	Approx 10m.
Tidal bore	Front wave up to 2m height followed by fast moving grade 2 white water.	Numerous periods of 2-3m waves with grade 3-4 tidal rapid s.	None known.
Landscape & Geology	Dominantly low-lying land backed by gently sloping hills (Cotswolds, Forest of Dean and Brecon Beacons).	Low-lying land and red sandstone cliffs surrounded by gently sloping hills.	Vast expanses of wetland and low-lying land backed by hills and high mountains.
Population	Approx 3 million.	Approx 300,000 (180,000 Minas Basin).	Approx 3000.
Land use	Urban, industry, agriculture, wetlands, tourism, major cities, transport infrastructure and power stations.	Agriculture, wetlands, infrastructure, tourism, towns and scattered settlements.	Fish camps, foraging and villages.

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4 Man's Response to Tidal Change

4.1 Introduction: Population

It is estimated that some 3 million people live around the Severn Estuary in the UK; approximately 300,000 around the Bay of Fundy in Canada; and some 3000 around the Penzhinskaya Guba in Russia. With less than 0.1% of the population, Penzhinskaya Guba offers a control site for an estuary with a tidal range similar in size to the Severn Estuary. This provided an opportunity to see how man lives and works with the tide and/or manages tidal change at an earlier stage of human occupation and development.

'Our history is embedded with the tides. The tides provided a unique opportunity for the ship building industry with a natural dry dock provided twice a day'.

Terri McCulloch, Bay of Fundy Tourism Partnership

This section describes mans' response to the tide in relation to the three objectives of the project outlined in Section 1.2: recognising the tide; living and working with the tide; and harnessing the tide.

4.2 Recognising the Tide

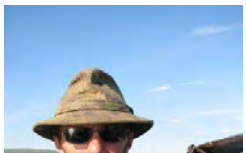
Public Awareness & Marketing the Tide for Tourism

Assess the level of community awareness of high tidal ranges. Explore existing and potential opportunities for promoting public awareness of the coastal environment (and climate change impacts) through marketing and tourism initiatives. Gather examples of interpretation methods and public involvement in tide-related activities (e.g. tidal bores). Compare management approaches to habitat protection for migrating birds, human impacts

Connections between people and their environment were explored. At each of the three estuaries, evidence was gathered to assess people's awareness of the tide, the large tidal range and how it influences their way of life.

Native Koryak dress.

The **Penzhinskaya Guba** is a remote area with a harsh climate, supporting small populations living in villages around its shores. It demonstrates how people first started to interact with tides. The shoreline offers resources from the sea to land-dwellers. Native Americans may have originated from this region of Russia (Turk, 2005) with evidence of early settlement some 4000 years old found in Kamchatka. Native populations in the Penzhino area were *Shore Koryaks* who settled in coastal areas, surviving on fish and whales from the sea, and *Reindeer Koryaks* who settled inland with subsistence living based around reindeer herds. There were 40-50 Koryak settlements and 28,000 Koryaki's at one time. A series of very small settlements existed along the northern shore of Penzhinskaya Guba. The first Russian settlements in Kamchatka were Cossacks from Magadan about 325 years ago. From the 1950s Russians and Ukrainians started settling in larger villages and towns such as Kamenskoye, Tilichiki and Palana around Penzhinskaya Guba. Until the 1990s there was a Soviet Union policy to populate remote areas of Russia. Manily and Kamenskoye expanded with cold war military developments. Today, the area is depopulating, with the communication station near Kamenskoye closed in 2003 and settlements such as Shestakova (approximately 15km west of Manily) now abandoned.



Russian on the River Penzhino.

In this sparsely populated area, people still live close to the tides. They rely on the tide much more directly for their existence. Barges bring produce and leave with the tides as there are no docks, harbours or piers. In summer months the abundance of mosquitos and other flies is

Penzhinskaya Guba & route of travel.

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Barges in the morning mist at Manily in Penzhinskaya Guba.

Interpreting the tide for business and pleasure.

Tidal bore viewing and rafting are a big attraction in the Bay of Fundy.

eased by winds around high tides. Native people relied heavily on whales for their meat, blubber and skins. Today, the techniques needed for whale catching have virtually been lost in history but the tide may bring in a whale which becomes beached and then harvested by the local people. Fishermen keenly watch the state of the tide for the safest and most optimal fishing times to prepare stocks for the long winter. The high level of dependence upon the tide means that many people are aware of the state of the tide. Several people suggested that younger children and elderly people were particularly sensitive to the highest tides. This contrasts heavily with the Severn Estuary, where many of the 3 million people living near the estuary know little about tides as they don't rely on them directly for living.

Human settlement around the Severn Estuary and Bay of Fundy dates back many centuries. The **Bay of Fundy** was occupied by natives who continue to have land rights around parts of the Bay. The area was first navigated by western European fishermen in the sixteenth century. Shorelines around the Bay of Fundy were first settled by the Acadians (from France) in the seventeenth century (1680s). New settlers dyked and drained the fertile saltmarsh and planted crops. Since then, settlement has developed around much of the Bay to its current level of around 300,000 people.

With the highest tidal range in the world, many organisations and businesses around the Bay of Fundy utilize the tide to promote tourism. The internet is used extensively to promote the highest tide in the world as a phenomenon to attract visitors from across the world. Many coastal towns use the '*tide*' and '*Fundy*' to market local business, as shown in the illustrations opposite. Nova Scotia and New Brunswick strongly market the Fundy tide for tourism, with tidal bore rafting and viewing sites, tidal trails, visitor and interpretation sites including an international reputation for promoting 'walks on the ocean floor'.

Comparatively, the **Severn Estuary** with the highest tide in Europe (Waters, 1947) is commonly known to have the second highest tidal range in the world, but is not well marketed and could be more widely promoted. Tidal tourism is not promoted in the UK or Russia. Sharing experience and marketing techniques from Canada offers useful opportunities for raising public awareness of the tide and for the development of tourism.

Tidal bores offer a mechanism to raise public awareness of the tide. The Severn bore occurs at predictable times each year. However, the tide is far less widely promoted as an attraction for tourists and most local people have not seen the tidal bores. Anecdotal evidence suggests that there are no tidal bores in the Penzhinskaya Guba of a similar nature to those experienced around the Severn Estuary and Bay of Fundy. The remoteness of northern Kamchatka means that opportunities for tourism associated with the Penzhinskaya Guba are significantly limited. Whilst this may be Russia's highest tidal range site in the world, it is extremely remote and expensive to reach. The author was almost certainly the first 'tourist' to visit the area purely to see the high tidal range!

'You stand and hold your breath, for in this land which holds neither mirages or volcanoes the river is flowing backwards, as a great wave a hundred yards broad and nine feet high comes rolling up the river…if only for an instant, to comprehend this magic of nature's sleight of hand'
'Severn Tide' by Brian Waters, 1947.

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Human interaction with the tide is particularly sensitive where migrating birds feed on mudflats. The **Severn Estuary** is designated to the highest level in European and UK law to protect its valuable habitats and birdlife – with up to 100,000 migrating birds currently using its mudflats during the winter. In the **Bay of Fundy**, over 1 million migrating shorebirds visit in summer on their way from the Canadian Arctic to South America. The wildlife of **Penzhinskaya Guba** is little researched but it has been suggested (Yuri Gerasimov *pers comm.)* that more than a million birds use the area in early summer. A recognised mechanism for making people aware of the potential conflict between man and nature in sensitive bird feeding areas, is through interpretation. Some of the best examples of outdoor interpretation and indoor visitor centre experiences can be found around the Bay of Fundy.

Interpretation platforms and panels lead to higher levels of public awareness of the tides and respect for natural habitats and species.

Summary: Recognising the Tide

Public awareness of the tide in the Penzhinskaya Guba area is very high as people rely on the coast for transport, fishing and living. It is higher than amongst people living around the Bay of Fundy and particularly the Severn Estuary. Urbanisation around the Severn Estuary has separated people from the need to live with an understanding of tidal patterns. The developed western lifestyle around the Bay of Fundy is similar to that around the Severn Estuary. However, marketing of the tide around the Bay of Fundy, use of the tide for branding businesses and tidal tourism, has maintained people's connection with the tides.

4.3 Living & Working with the Tide

Land Use Management & Flood Risk Planning

Assess the extent of coastal protection and flood defence measures and future options. Due to climate change there is increasing pressure on inter-tidal habitats with sea level rise and the risk of habitat and species loss due to coastal squeeze[1]. Compare habitat and landscape change in environments with high and low population densities. How adaptive are approaches to shoreline management and development planning.

The second objective of the fellowship was to look at how land use has influenced shoreline change. In the UK and Canada, land reclamation has led to the development of flood and coastal defences to protect agricultural land, people and property. Estuaries with high tidal ranges are likely to experience significant impacts from rising sea levels and increased storminess due to climate change. Pressure on existing defences is therefore likely to increase.

Land use is more intensive where there is a greater settled population, as shown in the table comparing land use of the three sites (see p.8). Around **Penzhinskaya Guba** where there is a low population density, there is no agricultural land due to the tundra. Only allotment plots within the villages provide vegetables and flowers. People have settled near the coast and fish camps dot the shoreline. Time in the summer months is spent foraging in the tundra for berries and fishing, gutting, cutting and drying large quantities of fish to last through the winter months. Land use has not led to modification of the shoreline.

Early settlement in Europe has led to more intensive land use and a higher population concentration. Land originally drained for agriculture has been subsequently developed for industrial and residential use. As a result, approximately 80% of the shoreline around the **Severn Estuary** is artificial with flood banks and sea defences, many forming a solid wall of concrete and rock armour. Some 60-70% of the shoreline around the **Bay**

Coal barges load up for the winter months in Penzhinskaya Guba.

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Concrete defences at high water mark along the Severn Estuary shoreline.

of Fundy has also been altered with flood banks to reclaim land for agriculture. It is less obvious than around the Severn, because the majority of defences are earth embankments, with rock or timber reinforcements only where necessary to protect property. In addition, many shoreline areas around Fundy have a 'buffer' of saltmarsh, typically 100m wide (Kolstee *pers.comm.*), providing a natural form of coastal protection in front of the earth embankments. Around the Severn, high water often extends right up to coastal defences. Inter-tidal habitats are 'squeezed' and eventually lost. The shorelines around both the Bay of Fundy and the Severn Estuary have both been significantly modified, but there is more flexibility within the Fundy system for the movement of sediment and habitats to absorb the energy of the tides. With a very high population concentration now living within a few miles of the Severn Estuary and increasing pressure from climate change impacts, there is a need to find sustainable solutions for future flood defence and coastal protection.

Reinforced embankments and 100m saltmarsh left to act as a natural buffer zone in the Bay of Fundy.

No comparison can be made between the development pressures experienced between the Severn Estuary and the wilderness of Penzhinskaya Guba. However, the shaping of the land by a tide not hindered by defences in Penzhinskaya, provided an opportunity to see how the shoreline and landscape of Britain and Canada could have looked prior to settlement and land reclamation. This provided a useful insight for future planning of the Severn. Lessons are still being learnt about the value of 'working with the tide' when it comes to coastal protection around both the Severn and Fundy. The need to plan for rising sea levels and increased storminess has resulted in the Environment Agency negotiating with landowners to promote schemes for habitat restoration & managed re-alignment of the shoreline. The approach to flood risk and shoreline management now being adopted in the UK may offer useful experience for future shoreline management policy and practice in Canada.

Natural shoreline with 50-200m marshland naturally protecting people and property around Penzhinskaya Guba.

Vast expanse of mudflats and saltmarsh upstream of Manily where the River Penzhino meets the sea. The land around Penzhinskaya Guba is wilderness - apart from a handful of settlements and fish camps, there are hundreds of kilometers of untamed land. The tide is free to roam!

Summary: Living and Working with the Tide

Population concentration has a significant influence on land use. With over 3 million people living around the Severn Estuary there is intensive pressure on low-lying land for industrial, residential, agricultural and infrastructure use. With some 10% of that population living around the Bay of Fundy, land use is under less pressure and most shoreline areas are still dominated by agricultural use with softer coastal defences. However, 60-70% of the Fundy shoreline is still backed by earth embankments. If development pressure increases there may be a pattern of changing land use similar to that experienced around the Severn. UK work on coastal flood risk and shoreline management is now highlighting the cost of maintaining expensive defences and looking towards returning previously reclaimed land back to the sea. Early settlers, illustrated here by people living around Penzhinskaya Guba, lived with the natural shoreline. This offered an example of how an untamed estuary with a similar tidal range to the Severn extends its floodwater over a vast expanse of land. The functioning of this natural ecosystem suggests that significant areas of land around Fundy and Severn need to be given back to the tide to avoid costly maintenance of concrete defences under increasing climate change pressures.

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4.4 Harnessing the Tide

Renewable Energy Options

Identify past, present and proposed options for harnessing tidal energy. Also due to climate change, there is increasing political attention towards opportunities for renewable energy. Tidal power plants could provide a useful source of energy, but technologies are relatively young. Make links with academic, government and commercial organisations involved in assessing the potential for renewable energy using tides.

The potential for tidal power generation is under the spotlight as a source of renewable energy. Estuaries and coastal areas experiencing the highest tides are likely to offer significant opportunities for tidal power generation. Whilst the technological options are relatively young, there are some examples of existing tidal barrages:

- La Rance (Brittany, France) 240 MW plant (1967);
- Kislaya Guba (White Sea, Russia) 0.4 MW plant (1968);
- Annapolis Royal (Nova Scotia, Canada) 18 MW plant (1983);
- Jiangxia Plant (China) 3.9 MW plant (1985).

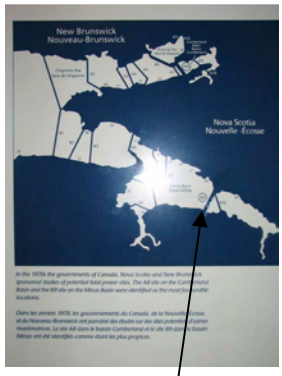
The oldest tidal power plant in the world is situated on La Rance estuary in France. It demonstrates the ability to generate electricity from the tide through a barrage. However, for comparison with the Severn Estuary, the Bay of Fundy is more similar in terms of its large tidal range and floodplain estuary with a high silt concentration. The Canadians' views on tidal power options for Fundy and experience from the Annapolis Royal tidal power plant in Nova Scotia, offers useful information for the Severn.

Local of Annapolis Royal tidal power plant in the Bay of Fundy.

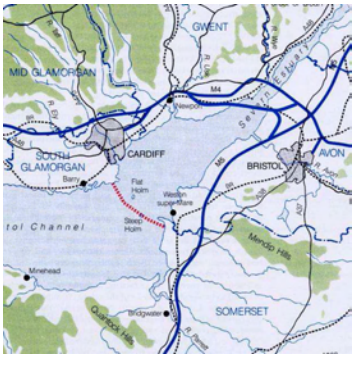
The potential for generating energy from the **Bay of Fundy** tides was first suggested in 1910 by W.R. Turnbull, an engineer and inventor from New Brunswick. Over the next 50 years there were sporadic and unsuccessful attempts at development. The 1960s saw increasing investigations, with the Atlantic Tidal Power Programming Board making the first examination of the tidal resource as a whole and identifying the most promising sites for tidal barrages (Conley & Daborn in *Energy Options for Atlantic Canada*, 1983). In the late 1970s, improvements in technology, understanding of the resource and the increasing price of fuel, led to designs for two sites that appeared to be economically feasible. The greatest potential was shown by the Minas Basin-Cobequid Bay barrage option (site B9) as shown on the diagram opposite. Capacities of between 4000 and 5300 MW were estimated to give an annual energy output of about 14000 GWh, potentially up to 20000 GWh. Construction costs in 1981 were estimated at just over $6 million with production beginning after 8 years of construction time. It was envisaged that the B9 site would contain 128 turbines in an 8km barrage and impound more than 300km^2 of tidal water in Cobequid Bay. Investigations during this time illustrated significant potential impacts of a barrage, particularly in relation to changing the tidal regime. Hydrodynamic numerical modelling undertaken by the Tidal Power Review Board indicated that the construction of a barrage in the upper part of the Bay would result in:

- reduction of tidal range in the vicinity of the barrage;
- increase of tidal range in the lower Bay and Gulf of Maine (USA).

A barrage at site B9 in the Minas Basin was estimated to cause a 13cm rise in tidal amplitude in Boston, New England (USA), which was considered unacceptable by the Americans!



Site B9 across the Minas Basin



Potential location of a Severn Barrage scheme shown in red (approx 10 miles long).
Source: Kerr/Severn Tidal Power Group

After decades of seeming dormancy, engineers and others interested in exploiting the powerful tides of Fundy are coming forward again with new proposals for harnessing the flowing waters in a purportedly more

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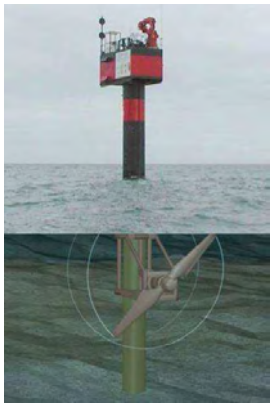
environmentally benign manner. Recent studies have examined the viability of tidal current power and pilot projects are likely to follow soon. Recently (2007-08) consultation has been underway on a Strategic Environmental Assessment of tidal power options. Options under consideration include the Marine Current Turbines *SeaFlow* and *SeaGen* turbines which have been designed in the UK. The technologies are still young but it is not too early to prioritise options for pilot testing the technology at appropriate sites – as has been undertaken in the Bristol Channel just north of Foreland Point near the Severn Estuary.



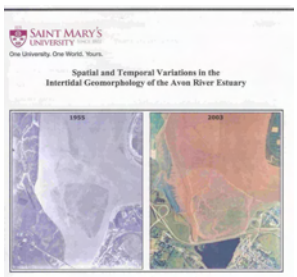
Monopile tidal stream device being trialled in the Bristol Channel, UK.
Source: Entec

The tidal power plant at Annapolis Royal in the Bay of Fundy became operational in 1983. It's purpose was to evaluate the performance of a single large diameter (7.6m) straight flow (*straflow*) turbine of the kind that might be used in a larger Fundy scheme. As one of 130 equivalent turbines that would be needed for a tidal barrage, it has mainly been proved to be effective. With the flow of 21 million m^3 of water in and out of the Bay of Fundy at each cycle of the tide, Nova Scotia Power estimated a potential power generation of 20 billion kWh, three times the consumption of Nova Scotia.

Construction of the Annapolis Royal tidal power plant required 850 cubic yards soil, 27,000 cubic yards concrete and 2400 tons of reinforced steel. The casing for the turbine was 152ft long with a 250 ton distributor ring. The turbine itself weighed 162 tons and is 25 ft in diameter. The 18 'wigator' gates have 50 revolutions per minute and produce 20 MW of power, generating 35 million kWh of electricity per year. The turbine generates electricity for 6 hours during low tide and is connected to the Nova Scotia Power Grid System.

However, it should be noted that the physical environment in which this scheme operates in the outer Bay of Fundy, is very different from that of the upper Bay of Fundy, where there is a higher tidal range and higher silt concentration in the water column (as is the case when comparing the Severn with La Rance in France). Nevertheless, it has provided useful information about the operation of a tidal turbine. The upstream and downstream implications and environmental impacts of this tidal power plant are still being investigated. Upstream, the waterspace is popular for recreation and there is significant investment in water quality monitoring. Downstream there are new areas of shoreline erosion which have required additional coastal protection.

At the present time there is limited consideration of tidal barrage options for the Bay of Fundy. This is due to the predicted environmental impacts of a barrage plus experience of how tidal causeways in the upper Bay of Fundy have negatively affected tidal and river systems. A causeway across the River Avon in the Minas Basin resulted in rapid accumulation of sediment on the downstream side of the barrier and subsequent development of new saltmarshes. At Moncton on the River Pedicodiac, the dynamic equilibrium of the river has shown no signs of stabilising after 15 years and resulted in unpredictable flooding problems. Scientists have recommended removal of the causeway and are planning how to return the river to its natural ecosystem. Tidal stream turbines for harnessing tidal power from Fundy are now viewed more favourably than the barrage options as they carry less risk to society and the environment.



Aerial views of the River Avon before and after impoundment by a road causeway.

Increasingly, different tidal energy options are being researched and evaluated for their cost-effectiveness. Momentum is building in Canada for a pilot scheme in the Bay of Fundy. At the same time, Severn Barrage proposals of the late 1980s-early 1990s are being re-visited. A report published by the UK's Sustainable Development Commission (SDC, October 2007) gave clear recommendations to Government about the potential for renewable energy from the Severn and the value of re-considering the Severn Barrage. A 2 year feasibility study into tidal power options, to consider barrage and other options, was commissioned by the Government in early 2008.

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The potential for tidal power generation has also been recognized from Shelikova Bay and Penzhinskaya Guba in the Sea of Okhotsk (Bernshtein, 1996; Kowalik, 2004; Kowalik & Polyakov, 1998; Isachev, 2006). The proximity of supply to demand make tidal energy less likely to be utilized than in more developed parts of the world such as the Severn Estuary and Bay of Fundy. Nevertheless, the Penzhinskaya Guba contains the highest tidal range in Russia (13.9m) and it has been studied for its potential provision of tidal energy. Two potential tidal barrage alignments have been estimated:

i) 32km barrage at a 26m deep location; 6800 km^2 basin; 27000 MW; 72 billion kWh;

ii) 72km barrage at a 67m deep location; 20500 km^2 basin; 87000 MW; 4400 generating units with 10m diameter turbine wheels capable of producing 200 billion kWh annually.

Compared to the largest world hydro-power scheme in China (17700 MW) this scheme would be the largest ever proposed.

Potential tidal barrage routes across Penzhinskaya Guba.
Source: Isachev, 2006.

The extreme climatic conditions and ice within Penzhinskaya Guba for up to eight months of the year could make any tidal power scheme extremely challenging. The physical distance from supply of energy to demand is a significant constraint to development. Major consumers would be America, Japan, China or further south in the Vladivostock/Khabarovsk area of Russia, thousands of kilometres from Penzhinskaya Guba. As early as 1961 US specialists proposed a power grid project aimed at joining Russian and USA power systems across the Bering Strait. It has been suggested (Isachev, 2006) that the technical feasibility of wireless power transmission for long distances and the rapidly changing world energy situation should accelerate consideration of the Penzhinski tidal power plant project. However, since Soviet times there has been little further consideration of these tidal barrages and the focus for renewable energy generation has been elsewhere in the Sea of Okhotsk.

Coastline of the narrow part of Penzhinskaya Guba (site i) referred to above.

Minas Basin from Economy Hill looking towards Burntcoat Head across the Bay of Fundy. The site of the highest recorded tides in the world and the most favoured location for a tidal barrage in the 1980s.

Summary: Harnessing the Tide

The Bay of Fundy and Severn Estuary are leading areas for the development and application of tidal energy technology. The rapidly changing world energy situation, due to climate change security of energy supply, now demands full assessment of tidal power options. Experience from existing tidal power stations such as the Annapolis Royal tidal power plant in the Bay of Fundy and La Rance in France have proved the feasibility of the technology and provided some indication of the impacts on the ecosystem. However, tidal barrage development has yet to be proven in a high silt environment such as the upper Bay of Fundy or Severn Estuary. Experiences of rapid siltation and alteration of erosion and flooding patterns after the construction of tidal causeways around the Bay of Fundy have led to a cautious approach - combined with the political sensitivity of a significant rise in sea level in hundreds of km downstream in Boston, U.S.A. Feasibility studies including strategic environmental assessments are underway for tidal power options in the Bay of Fundy and the Severn Estuary. The potential for tidal power generation has also been recognized from the Penzhinskaya Guba despite huge distances between the supply and demand.

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5 Man and Nature's Response: Managing Tidal Change

5.1 Introduction: Sustainability

Population pressure on natural resources has a significant influence on our ability to achieve sustainable development. With less than 1% of the population living around the Penzhinskaya Guba and 10% around the Bay of Fundy compared to the Severn Estuary, observations between similar size and tidal range estuaries were made to assess how man has lived and worked with the tide or has managed tidal change.

5.2 Penzhinskaya Guba: Wilderness Living

Fish nets laid out for high tide catches in Penzhinskaya Guba.

Russian settlement has come to dominate native culture over the past 50 years, with now little evidence of Koryak traditions apart from well presented local museums. However, people still depend closely on the tide for fishing, fuel and transport. The way of life has similar characteristics to subsistence living around the Severn Estuary hundreds of years ago, illustrated by, for example, the use of lathe nets for fishing from the shoreline and seine netting from small boats. Today, people live closer to the tides than in Fundy or Severn.

Penzhinskaya Guba has provided insight into an 'original baseline' environment of an estuary with a 13-14m tidal range similar to the Severn Estuary. It provided some idea of the character of the Severn Estuary before it was so intensively developed.

5.3 Severn Estuary: Developed Society?

Industry and infrastructure around the Severn Estuary.

Coasts and estuaries contain some of Britain's most fragile and valuable natural habitats. People put huge pressure on these sensitive environments through industry, agriculture, housing and transport infrastructure. Sustainable estuary management is advocated by over 50 voluntary coastal partnership initiatives in Britain, one of which is the Severn Estuary Partnership. With over 3 million people living around the estuary in the cities of Cardiff, Newport, Gloucester, Bristol plus the towns and villages in between, there is huge development pressure on the Severn Estuary shoreline. Infrastructure is significant with motorways, two major bridge crossings, mainline railways including the Severn tunnel and commercial ports at Cardiff, Newport, Gloucester and Avonmouth. Aggregate extraction from the estuary is an extremely important resource, supplying some 90% of the construction industry in south Wales. Much of the land around the Severn Estuary has been reclaimed for development, with 80% of the shoreline now artificial through the establishment of coastal defences and flood protection structures. This level of development has changed people's lifestyles and begs the question of whether quality of life is better and what type of lifestyle is sustainable in the longer term.

5.4 Bay of Fundy: Achieving Sustainability

Fundy shoreline in New Brunswick.

With some 10% of the population compared to the Severn, the Bay of Fundy is under less pressure for development, yet 60-70% of its shoreline has still been reclaimed for agriculture and other development. Public awareness of the tide is much higher than around the Severn Estuary. Tidal tourism brings income into the economy and there appears to be wider recognition of the value of the Bay of Fundy to

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society. Pressure for development is therefore more likely to be balanced with natural processes.

Valuable observations were made between the role of the Bay of Fundy Ecosystem Partnership, the Minas Bay Working Group and the Severn Estuary Partnership – voluntary initiatives working to balance the management and use of estuaries. The evolving framework for coastal and marine governance is further ahead in Canada than the UK, which was useful to observe during development of the UK Marine Bill. Similarities could be drawn between the community-based Atlantic Coastal Action Programme (ACAP) in Canada and the voluntary work of Coastal Partnerships in the UK. The financial value of the ACAP initiatives and their role in leadership and community empowerment was demonstrated. They provide practical evidence of how to achieve sustainable development.

In Canada, Coastal Management Areas will enable communities to play a stronger role in issues affecting their future by matching local capabilities and development priorities to the opportunities and carrying capacities of the local ecosystem.

5.5 Conclusion: Sustainable Development or Management

In our society today, there are many references to sustainable development, particularly since the World Summit on the Environment and Development in Rio de Janeiro in 1992. Sustainable development is advocated as the future way of balancing the interests of people and the environment.

Initiatives such as the Severn Estuary Partnership and Bay of Fundy Ecosystem Partnership were initiated in the mid 1990s to advocate sustainable development at the local level. Since estuarine resources are so intensively used, these initiatives provide mechanisms to encourage sustainable planning and management. To aid their work it would seem necessary to understand a baseline environmental condition and identify an acceptable target for environmental limits and our quality of life. There is, however, no such 'agreed baseline' for managing the Severn Estuary. There are limits (in the form of consents) put on the exploitation of resources which are set and implemented by government bodies on a sectoral basis (e.g. fishing licences, industrial discharge licences and restrictions on activities within designated nature conservation areas). However, there is a limited overall perspective or analysis of how different resource demands and estuary-based activities influence the health of the whole ecosystem. The implementation of the European Habitats & Species Directives and more recently, the Water Framework Directive are beginning to introduce standards for ecosystem health and monitor activities which may effect them. In addition, the Severn Estuary Partnership has recognised the value of developing a 'State of the Estuary' report and data collation for improved mapping of the estuary. Further investment in this direction could help to identify sustainability criteria and limits.

Around Penzhinskaya Guba, there is currently little pressure for development and therefore the quality of the environment is barely threatened. However, should such a time come for significant development, for example in the event of oil exploration or a tidal power scheme, experience from the Severn Estuary and Bay of Fundy could be valuable in choosing the optimal path for long term sustainability. At the moment, the remoteness of the location means that this is a long way off! Instead, knowledge of Penzhinskaya Guba provided a useful insight to an original ecosystem and wider shoreline that would have existed around the Severn Estuary prior to land reclamation and intensive development. This understanding is valuable when considering the sustainability of

Development of society leads to more management of tidal change and less direct interaction between people and the tides. The challenges for sustainability are seen very clearly in coastal areas (due to high population concentrations) and particularly in dynamic high tidal environments where people and the tides have learnt to co-exist.

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future flood and coastal protection around the Severn Estuary. It may be necessary to return some of our land back to the tide.

An untamed tide in an estuary wilderness in Russia, compared to a highly developed estuary in Britain, starkly illustrates how far development can remove people from an understanding of their natural environment. Sustainable *development* implies that people can continue to develop with no end goal in sight. Perhaps a more appropriate term for the satisfactory co-existence between man and nature would be sustainable *management*; where human population demands are balanced with the natural environment at a level where we have achieved an acceptable quality of life for the long term. This, then, raises questions about what is sustainable and what is an acceptable quality of life; living in a smaller community closer to local resources (and the tide), or in a heavily populated suburban and industrialised area, where there is more freedom of movement but less connection to the natural environment (and the tide). Development of society leads to more management of tidal change and less direct interaction between people and the tides. The challenges for sustainability are seen very clearly in coastal areas with high population concentrations, particularly in dynamic high tidal environments.

6 Application of the Fellowship

6.1 Findings & Recommendations

The travelling fellowship was spent on field visits and linking with organisations responsible for resource management and research. The overall aim of the project, to compare approaches to managing tidal change and to establish links with organisations managing and/or researching the influence of the tide was fulfilled.

Arriving at Kamenskoye by the River Penzhino, July 2007.

The three overall objectives of the 'Managing Tidal Change' project have been explored and reported in separate reports: for the Bay of Fundy in the Phase 1 report and for Penzhinskaya Guba in the Phase 2 report.

The Bay of Fundy report was jointly authored with Maxine Westhead from the Department of Fisheries and Oceans, Canada. It concluded with a series of recommendations specific to collaboration between the Severn Estuary and Bay of Fundy, some of which have already been pursued through the Severn Estuary Partnership. This included hosting a keynote speaker from Environment Canada to the Severn Estuary Forum in 2007, the use of a 'Fundy Library' in the Severn Estuary Partnership office at Cardiff University by Government, NGOs and local organisations, and the ongoing development of a Marketing and Tourism Strategy for the Severn Estuary.

Cardiff Harbour Festival, August 2007.

The Penhzinskaya Guba report was prepared in collaboration with scientists Olga Chernyagina and Vadim Kirichenko at the Pacific Institute of Geography, Kamchatka Branch. It concluded with more general observations about the evolution of estuaries and their sustainable management. Since returning from Kamchatka, a joint paper was provided for the 2007 annual conference of the Pacific Institute of Geography Kamchatka Branch on the theme of 'Protection of Kamchatka's Biodiversity and Coastal Waters'. The Pacific Institute of Geography have collated new information through our collaboration for this field visit and hope to undertake further research in this remote area.

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6.2 Dissemination

This final report to the Winston Churchill Memorial Trust summarises the fellowship findings for the Trust and for general distribution. The Bay of Fundy (Phase 1) and Penzhinskaya Guba (Phase 2) reports produced from the fellowship are aimed at professional colleagues working around the Severn Estuary and all those involved in planning the trips or met during visits to Canada, Alaska and Russia. Specific avenues for dissemination and opportunities for future collaboration are shown in the appendices. Post-trip contacts are evolving for further dissemination of the research and to encourage further publicity, for which there is significant interest.

6.3 Conclusion

There are valuable comparisons to be made between coastal areas experiencing the highest tides in the world. Investigating the Severn Estuary in UK, the Bay of Fundy in Canada, and the Penzhinskaya Guba in Russia led to comparisons in approaches to flood risk management, tidal energy potential and marketing the tide for tourism.

Observing three estuaries with different scales of development illustrates the influence settlement has had on the coast and how people have managed tidal change. The Penzhinskaya Guba provided an excellent control site to see how a natural ecological system looks when un-hindered by coastal defences and land reclamation. It provided a holistic perspective which may guide future sustainable management of more developed estuaries, including decisions about coastal defence, flood protection and options for harnessing tidal energy.

Public awareness of the tide appears to be lower where there is a higher population density. However, there is significant recognition of the highest tides in the world around the Bay of Fundy, which are promoted for tourism through highly evolved interpretation. This will provide useful experience for raising awareness of the value of the Severn Estuary.

6.4 Personal & Professional Benefits

The opportunity to meet professional colleagues in other countries with very similar interests proved very rewarding. In addition to meeting people connected with Fundy tidal life and collating a significant amount of information, links have already been established through this visit for others in the UK and Canada to share experience. The possibility that this could be the first step in establishing a twinning association for building a longer-term collaborative arrangement is exciting.

The benefits of witnessing an estuary surrounded by wilderness, provided a valuable perspective on how we define sustainable management and whether limits should be set to ensure our future quality of life. The personal exploration to reach the Penzhinskaya Guba was a very real journey of a lifetime.

As indicated by the Director of the Winston Churchill Memorial Trust at the South West branch AGM in September 2007, most fellows realise the full benefit from their fellowships about 20 years after completion, so future personal and professional benefits remain to be discovered!

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6.5 About the Author

Natasha on the shores of Penzhinskaya Guba.

Natasha Barker from the Severn Estuary Partnership based at Cardiff University in the UK, worked as an Estuary Partnership Officer since 1998. She established and Chairs the English Coastal Partnerships Working Group, which is informing development of Integrated Coastal Zone Management Strategies for England & Wales and the UK's proposed Marine Bill. She has been involved in several EU funded projects relating to integrated coastal zone management and river catchment management. Natasha previously worked as an Environmental Scientist for a consulting engineering firm undertaking Environmental Impact Assessments of coastal protection and flood defence schemes. She was involved in developing the Black Sea Environmental Programme in the early 1990s. Her interest in Russia and the former Soviet Union states continues through consultancy work on a range of projects in Ukraine, Georgia and Russia, relating to coastal management and public awareness.

6.6 Acknowledgements

The Winston Churchill Memorial Trust provided the financial and administrative support for this 'trip of a lifetime'. I am very grateful for their flexibility in allowing me to phase the fellowship over two years and for providing financial support to make the trip to Far East Russia viable.

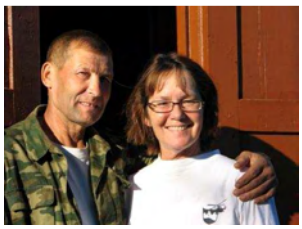
I am grateful to the many people around the Bay of Fundy who gave generously of their time to share information and discuss their views on public awareness of the tide, flood risk planning and tidal energy. Maxine Westhead in the Department of Fisheries & Oceans (DFO) Canada was instrumental to the success of this research.

Many people were involved in guiding me towards reaching my ultimate destination of Manily at the mouth of the Penzhinskaya Guba estuary. Without any one of these people in the chain of contacts, it is likely that the trip would not have been successful. *Spasibo bolshoi!*

The support of Cardiff University, the Seven Estuary Partnership, family and friends has been invaluable.

Natasha Barker, March 2008

Maxine Westhead, tidal rafting on the River Shubenacadie with Natasha.



Martha and Yuri in Yelisovo, Kamchatka.

Arriving at Manily on the Penzhinskaya Guba, 22nd July 2007.

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http://www.cbc.ca/nb/story/nb_tidepower20051018.html
http://www.cbc.ca/story/canada/national/2005/10/19/tidal-power051019.html
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Report on potential sites available **-** The report entitled "Nova Scotia Tidal In-Stream Energy Conversion (TISEC): Survey and Characterization of Potential Project Sites" is available at http://www.epri.com/oceanenergy/streamenergy.html#reports. The Minas Channel and Minas Basin were identified as the only TISEC sites in North America with the potential for central power generation.

Firm hopes turbines will drive Bay of Fundy tidal power. A Windsor company wants to harness the Bay of Fundy's immense tidal power to generate electricity. ATEC Power Inc. has reached an agreement with an American company, UEK Corp., to use its tidal turbine technology to build and use these underwater

turbines in Atlantic Canada. **-**Article in Halifax Chronicle Herald, March 24, 2006 by Judy Myrden, Business Reporter. For complete story go to: http://www.herald.ns.ca/Search/492121.html

www.russia-ic.com/news/show/929 *Russian power plants soon to utilise tidal energy 24.06.05.*

A 'Fundy Library' is stored at the Severn Estuary Partnership office in Cardiff University (Contact: Natasha Barker on 029 20874713 / severn@cardiff.ac.uk).

Definition of Tidal Range and Tidal Bore

Definition of Tidal Range *(Source:http://en.wikipedia.org/wiki/Tidal_range)*

The **tidal range** is the vertical difference between the highest high tide and the lowest low tide. In other words, it is the difference in height between high and low tides. The most extreme tidal range will occur around the time of the full or new moons, when gravity of both the Sun and Moon are pulling the same way (new moon), or exact opposite way (full). This type of tide is known as a spring tide. During neap tides, when the Moon and Sun's vectors make a right angle at the Earth, the difference between high and low tides is smaller. The typical tidal range in the open ocean is about 0.6 meters (2 feet). As you get closer to the coast, however, this range gets much greater. Coastal tidal ranges vary globally and can differ anywhere from 1.8 meters to 3 meters (6–10 feet). The world's biggest tidal differential occurs in the Bay of Fundy in Eastern Canada, where the sea level changes by up to 17 meters (55 feet) during the day. Ungava Bay in Northern Quebec, north eastern Canada, is believed by some experts to have higher tidal ranges than the Bay of Fundy (about 17 metres or 56 ft), but it is free of pack ice for only about four months every year, whereas the Bay of Fundy rarely freezes. What is generally regarded as the next highest tidal range occurs in the Bristol Channel in the UK, where sea levels change by some 15 meters (49 feet). The smallest tidal ranges occur in the Mediterranean, Baltic, and Caribbean Seas.

Definition of a Tidal Bore *(Source: http://en.wikipedia.org/wiki/Tidal_bore)*

A **tidal bore** (or just **bore**, or **eagre**) is a tidal phenomenon in which the leading edge of the incoming tide forms a wave (or waves) of water that travel up a river or narrow bay against the direction of the current. As such, it is a true *tidal wave* (not to be confused with a tsunami).

Bores occur in relatively few locations worldwide, usually in areas with a large tidal range (typically more than 20 feet between high and low water), and where incoming tides are funnelled into a shallow, narrowing river via a broad bay. The funnel-like shape not only increases the height of the tide, but it can also decrease the duration of the flood tide down to a point where the flood appears as a sudden increase in the water level.

Bores take on various forms, ranging from a single breaking wavefront—effectively a shock wave—to 'undular bores' comprising a smooth wavefront followed by a train of solitary waves (solitons). Larger bores can be particularly dangerous for shipping, but also present opportunities for river surfing.

APPENDICES

A Phase 1 Executive Summary, Itinerary & Contacts

B Phase 2 Executive Summary, Itinerary & Contacts

C Outputs from the Fellowship

D Opportunities for Collaboration and Dissemination

E Post-trip Contacts

F Post Project Notes

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A Phase 1 Executive Summary, Itinerary & Contacts

The Bay of Fundy in Canada is widely known to experience the highest tidal range in the world. The Severn Estuary in the UK is known to experience the 2nd highest tides in the world after the Bay of Fundy. The author's work for the Severn Estuary Partnership motivated this research project to compare approaches to current issues affecting the future use and management of estuaries. In particular the potential impacts of climate change, predicted sea level rise, storms and tidal surges are likely to have a significant affect on estuaries experiencing the highest tides in the world.

The location of estuaries with high tidal ranges puts the Severn Estuary into context with other high tidal range sites. A very remote estuary in Far East Russia called the Penzhinskaya Guba was identified as a third estuary for study. It was considered a useful contrast to the Bay of Fundy and Severn Estuary due to the very low population density and undeveloped character of the area. It provided a baseline environment from which to compare the influence of an unrestrained tide with the more developed shorelines of Fundy and Severn.

The report from Phase 1 of the project was completed after one month spent in Canada & Alaska. It describes the aim and objectives of the research and travel itinerary for the project. Site descriptions for the three estuaries in the project are provided. The three objectives identified as the focus for the research across the three sites, resulted in the following main findings from the visit to the Bay of Fundy:

i) Public awareness and marketing the tide for tourism
Public awareness of the tide around the Bay of Fundy is very evident through marketing and branding of *Fundy* and *tide*-related names in retail, financial and visitor services. Advanced use of interpretation to promote the Bay of Fundy attracts many visitors and international tourists. The publicity and interpretation methods used for Fundy could offer significant scope for improving awareness of the value of the Severn Estuary.

ii) Land use management and flood risk planning
A similar history of land reclamation has led to flood defences around 60-80% of the shoreline of both Fundy and the Severn. However, there are contrasts between flood defence and coastal protection structures. Highly engineered defences around the Severn offer less flexibility for future adaptation to sea level rise than earth embankments with wide natural habitat buffer zones typical around the Fundy shoreline. Techniques for managed re-alignment of the shoreline around the Severn could be informed by learning from the natural processes around the Fundy shoreline. Planning responses to future development pressure around Fundy could be informed by the experiences from the Severn.

iii) Renewable energy options
Annapolis Royal Tidal Power plant provided an example of an operative tidal power plant based on tidal range technology. It was a pilot scheme for larger tidal barrage proposals in the upper Bay of Fundy during the 1980s. Proposals for harnessing tidal power from Fundy are now focusing on tidal stream technology. This contrasts significantly to feasibility studies for the Severn which are now re-considering the Severn Barrage, alongside other options to harness the tidal range. Tidal causeways in the Bay of Fundy have caused significant and unpredictable siltation, flooding and erosion impacts on the river systems. This has resulted in a higher perception of the risks associated with tidal barrages.

The difference in population, with less than 10% around Fundy compared to the Severn, is an important characteristic that influences people's response to recognising, living with and harnessing the tide.

The coastal governance framework in Canada is examined to aid comparison with the management structures and roles of different organisations working within the Severn Estuary Partnership. Progress in Canada with legislation and policy for marine and coastal planning, plus experience with local community initiatives, proved useful for the author's work with the Severn Estuary Partnership; for input to the proposals for a UK Marine Bill; and development of the English Coastal Partnerships Working Group.

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The full findings, opportunities for future collaboration and recommendations for action resulting from the visit to the Bay of Fundy are described in detail in the Phase 1 report. It also includes a review of the aims for Phase 2 of the fellowship, informed by a visit to scientists at the University of Alaska Fairbanks. They had researched tides in the Sea of Okhotsk including Penzhinskaya Guba, the third estuary involved in this research. Findings from Phase 2, through the visit to Russia, are provided in a separate Phase 2 report.

CANADA & ALASKA 2006 Phase 1

DATE	LOCATION	CONTACT/ VISIT	NOTES
***KEY:* Meetings/ Site Visits**	***Field study***	***Travel***	***Other - not directly related to the project.***
Fri 20 Jul – Sun 23 Jul FLIGHT: London – Montreal & overnight stay. TRAIN Montreal – Halifax. Familiarisation.			
Mon 24 Jul 06	**Bedford Institute of Oceanography (BIO), Dept Fisheries & Oceans (DFO) Halifax**	**Maxine Westhead,** Project Leader, Bay of Fundy/Gulf of Maine, Fisheries and Oceans Canada - introduced to staff in Oceans & Coastal Divisions	CONTACT: **Tim Hall**, Head of Oceans Division. **Dave Duggan**, Head of Coastal Management Division. **Scott Coffen-Smout** (knows Wales UK) & **Glen Herbert** (knows RB & HS @ CU, went to Bangor Uni), Oceans & Habitat Branch - wkg on Scotian Shelf Plan
Tue 25	**BIO, DFO Halifax**	**Maxine Westhead**	CONTACT: **Paul McNabb**
	BIO, DFO Halifax	**Anita Hamilton**, Stewardship Coordinator,Habitat Management Div	Habitats, remediation, fish passes, self-regulating tidal exchange technology.
Wed 26	**Truro**	**Hank Kolstee,** Supervisor, Land Protection, Agriculture Resource Stewardship, Nova Scotia (Truro).	
	Parsboro	**Terri McCulloch**	CONTACT: **Michael Fuller** (Pegasus Paragliding) & **Christa**
Thu 27	**Shubenacadie, nr Truro**	**Shubenacadie River Runners Ltd.**	CONTACT: **Brian & Kim vandeCrie**
	Halifax	**Danika van Proosdij**, Associate Professor, Dept of Geography, Saint Mary's University, Halifax	Tracks changes over time as a result of the Avon River tidal barrier
Fri 28	**Wolfville**	**Minas Bay Working Group meeting**	CONTACT: **Mike Brylinsky**, Director of Working Group (outgoing). **Anna Redkin** Director of Acadia Centre for Estuarine Research & Secretary to BoFEP & MBWG. **Justin Huston** (Coasts, Provincial Gvt). **Peter Wells**, Director of Working Group (incoming).
Sat 29	SW Nova Scotia	Halifax – Crescent Beach/Cape LaHave	Stops at Lunenburg and Bush Island Provincial Park (kayaking).
Sun 30	SW Nova Scotia	Crescent Beach/Cape LaHave - Bear River	Stops at Kejimkujik National Park (seaside adjunct); Lockeport; Clarks Harbour; and Cape St. Mary.
Mon 31	**Annapolis Royal & Digby**	**Stephen Hawboldt**, Clean Annapolis River Project & Annapolis Royal Tidal Power Plant	Tide clock purchased at: Kathy's Gifts & Collectables. 50 Water Street, Digby NB VOV 1AO. (902) 245 1253
	Newton Ville (nr Wolfville)	**Tracey Horsman (GIS), DFO, BIO & Jamie Gibson, DFO, BIO**	Overnight stay in Newton Ville, nr Wolfville
Tue 1 Aug	**Wolfville**	**Graham Daborn**, Director, Arthur Iriving Academy for the Environment, Acadia University	
	Wolfville area	**Nova Scotia Dept of Natural Resources**	**Rancy Milton**, Manager, Wildlife Resources (Wetlands & Coastal Habitats); **Sherman Boates**, Manager, Wildlife Resources Biodiversity (shorebirds & species @ risk), **Reg Newell**, Stewardship Coordinator, Eastern Habitat Joint Venture. Nova Scotia Provincial Gvt
Wed 2	**Dartmouth**	**Larry Hildebrand**, Environment Canada	
	BIO, DFO Halifax	**Charlie O'Reilly**, DFO, BIO	Tidal prediction & survey inc. Ungava Bay expedition research.
Thu 3	**BIO, DFO Halifax**	Maxine Westhead	
Fri 4	**BIO, DFO Halifax**		Met **Harry Thurston**, author of many books on the Bay of Fundy including *Tidal Life* which is widely available.
Sat 5	Halifax - Tiverton, NS	**Grand Pre marsh reclamation and interpretation site**	North American Right Wales (25)
Sun 6	Tiverton - Alma, NB	**Digby; St Martins, Fundy Trail Parkway; Fundy National Park**	CONTACT: **Tracey Kohlruss**, Visitor Services, Fundy National Park (506 887 6009) tracey.kohlruss@pc.gc.ca. Peter Etheridge,

			Director of NP?
Mon 7	Alma - Advocate Harbour, NS	**Cape Enrage, Hopewell Rocks, Moncton, Fort Lawrence**	CONTACT: **Tim Milligan**, BIO Dartmouth - survey work at Moncton.
Tues 8	**Advocate Harbour- Halifax**	**Parrsboro – Terri McCulloch**	
Wed 9 FLIGHT: Halifax - Montreal + Montreal – Vancouver			
Thur 10 FLIGHT: Vancouver - Anchorage - Fairbanks, Alaska			
Fri 11 – Sun 13	Fairbanks	Familiarisation	
Mon 14	**University of Alaska Fairbanks**	**Professor Zygmunt Kowalik**, Institure of Marine Science.	Researching ocean dynamics inc modelling tsunamis
	University of Alaska Fairbanks	**Dr Igor Polyakov**, Frontier Research System for Global Change, International Arctic Research Centre.	Researching causes of global warming
Tue 15 TRAIN: Fairbanks – Anchorage			
Wed 16 – Fri 18	Whittier	Blackstone Glacier	Holiday: sea Kayaking
Sat 19 – Fri 24	Valdez	Columbia Glacier & Glacier Ilsland	Holiday: sea kayaking & camping
Fri 25 Aug FLIGHT: Anchorage - Vancouver – London			

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B Phase 2 Executive Summary, Itinerary & Contacts

Penzhinskaya Guba experiences the highest tidal range in Russia, of a similar range to the Severn Estuary in the UK (where the author works). Together with the Bay of Fundy in Canada, which is known to have the highest tidal range in the world, this project looked at three estuaries to compare their characteristics in relation to human use and management. In particular the potential impacts of climate change, predicted sea level rise, storms and tidal surges are likely to have a significant affect on dynamic estuaries experiencing the highest tidal ranges in the world.

Penzhinskaya Guba was considered a useful contrast to the Severn Estuary and Bay of Fundy due to the very low population density and undeveloped character of the area. It provided a baseline environment from which to see the influence of an unrestrained tide, compared to the more developed shorelines of Fundy and Severn.

Phase 1 of the project involved one month spent in Canada and Alaska during 2006 to research the Bay of Fundy which is described in a separate report. This report from Phase 2 of the project was completed after one month spent in Kamchatka to visit Penzhinskaya Guba in 2007. It describes the aim and objectives of the research and how this remote estuary was reached. Findings from a brief assessment of the highest tides in the world are given, with site descriptions, for the three estuaries studied. The three objectives which were the focus for the research across the three sites resulted in the following main findings from the visit to Penzhinskaya Guba:

i) Public awareness of the tide
Penzhinskaya Guba has a very low population density where people's livelihoods are closely linked to the tide for transport, fishing and living - where sea breezes limit the mosquito's. This contrasts with the Severn Estuary where a very limited number of people's lives are directly influenced by the tide. Even when compared to the impact of publicity and interpretation methods used around Fundy, public awareness of the tide is higher around Penzhinskaya. There is no tourism. No clear evidence was found for a tidal bore or tidal rapids, but it could not be ruled out due to the sparse population and vast area which could not be surveyed fully during the duration of the field study.

ii) Land use management and flood risk planning
Native Koryaks settled around Penzhinskaya in small settlements, living a subsistence lifestyle on fishing and whale hunting. Around 300 years ago, the first Russian settlement began with Cossacks migrating to the area. From the 1950s people started settling in larger towns and the population increased with a Soviet Union policy to populate remote areas. Since the end of the cold war and the Soviet Union, the population is decreasing. Few traces remain of the native way of life of the Koryaks in the main settlements. However, beyond the towns and villages there is little human influence and this is still a vast area of wilderness. Viewing a coastal area with less than 0.01% of the population of the area surrounding the Severn Estuary, provided a unique opportunity to witness the influence of the tide where none of the shoreline has been reclaimed for agriculture or made static with coastal defences. This provided an insight into the historical extent of the Severn which is useful for current work on flood risk management strategies and shoreline management planning - where planners & engineers are looking for greater understanding of natural processes.

iii) Renewable energy options
Even in such a remote area, proposals for generating tidal energy have been considered. When compared to other existing and potential hydro-electric power schemes or tidal barrages, the potential provision of tidal energy from a barrage across Penzhinsksaya is significantly higher. However, serious limitations are the extreme climatic conditions and the physical distance from the supply of energy to the consumers.

The full findings from the visit to Penzhinskaya Guba are described in sections relating to the three objectives outlined above. The report concludes with observations on sustainable development and management of estuaries. It highlights that for the Severn Estuary Partnership it would be useful to have a better understanding of the baseline environment and natural processes. This would inform future flood risk management, shoreline planning and support the feasibility studies for tidal power options.

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RUSSIA 2007 Phase 2

DATE	LOCATION	CONTACT NAME & ORGANISATION	NOTES
KEY: Meetings	*Field study*	*Travel*	***Other - not directly related to the project.***
Thu 5th July	**Moscow**	**Vassily Spiridinov (Marine Branch) World Wide Fund for Nature**	Advice and contacts
Fri 6th July	**Moscow**		Site-seeing
Sat 7th July FLIGHT: Moscow 1400 - Petropavlovsk Kamchatskiy 1000 Sunday			
Sun 8th July	**Yelisovo**	**Martha Masden, Diligens - Explore Kamchatka (Travel Agency)**	Arranged visa invitation, permit & registration in Petropavlovsk-Kamchatskiy. Provided B&B accommodation, contacts and logistical support.
Mon 9th July	**Yelisovo**	**Laura Williams, Director, World Wide Fund for Nature (WWF) Kamchatka/Bering Sea Ecoregional Office**	Provided contacts and advice.
	Petropavlovsk-Kamchatskiy	**Dr Robert Mosieev & Olga Chernyagina, Pacific Institute of Geography, Kamchatka Branch**	Met with Yigor (translator). Explored common ground over salt marshes, tidal estuarine ecology and coastal management.
	Yelisovo (WWF office)	**Boris Lezhni, Koryakski Duma (met in WWF office)**	Provided local information and travel advice.
Tue 10th July	**Petropavlovsk**		Purchasing flight ticket to Tilichiki & telephone calls to potential contacts.
	Yelisovo	Olga Romanenko, Ecological & Environmental Consultant	Met at Martha's B&B. Working on Kuril Islands project.
Wed 11th July	**Yelisovo**	**Yuri Gerasimov, Ornithologist**	Met in Yelisovo with Yigor (translator).
Thu 12th July	**Yelisovo**	**Vadim Kirichenko, Hydrologist, Pacific Institute of Geography, Kamchatka Branch**	Accompanied on trip from P-K to Penzhinskaya Guba and back (3 weeks).
	Paratunka hot springs	Rodney Russ, Heritage Expeditions	Offered to put me in contact with international ornithologists, including those living near the Severn Estuary.
Fri 13th July FLIGHT - small plane 'Koryak Air': Yelisovo 1430 - Tilichiki 1800			
Sat 14th July	**Tilichiki**	**Valeriy** (local contact provided by Igor Anatolovich)	Walked approx 3km along coast to the south, around village and met local people. National Geographic team departed.
Sun 15th July	**Tilichiki**		Walked approx 8km along coast to the north.
Mon 16th July	**Tilichiki & Korf**	**Zamanov Izmayudin Ziyodinovich**	Waiting at the airport for a helicopter. Met local policeman from Manily.
Tue 17th July	**Tilichiki & Korf**		Waiting at the airport for a helicopter.
Wed 18th July	**Tilichiki**	**Vadim Gennadivich Martinov, Director, Koryakski Reserve**	Waiting for helicopter, meeting local people and Director of nearby reserve.
Thu 19th July FLIGHT - Helicopter 'Koryaksi Air': Korf 2030 - Kamenskoye 2200			
Fri 20th July	**Kamenskoye**		River Penzhino - walk up and downstream of Kamenskoye.
	Kamenskoye	**Igor Anatolovich, Penzhino Administration & Boris Lezhni, Head of Koryakski Duma**	Discussions about River Penzhino, Penzhinskaya Guba, local communities and the Severn Estuary.
	Kamenskoye	**V.C. Cobenini, Director of the Museum**	
	Kamenskoye	**Vassily & Galina Dimitrievich**	Provided accommodation in their home for 3 nights, local information, road transport locally and arranged trip on barge to Manily.
	River Penzhino fishcamp, 10km upstream of Kamenskoye	**Mosyi Kamen, Sergiy Moiseev and others, local fishermen**	Discussions about River Penzhino, Penzhinskaya Guba and Severn Estuary tides and fishing.
Sat 21st July	**Kamenskoye surrounds**		By road west of Kamenskoye - radio communications station on hill and east of Kamenskoye.
Sun 22nd July BARGE: Kamenskoye 1100 - River Penzhino until 1800. Stuck on sand-bar approx. 20km downstream - returned to Kamenskoye by small boat. **JEEP: Kamenskoye 2000 - Manily 2130**			
Mon 23rd July	**Manily**	**Oleg Alexeivich Isaev, Director of Manily School** (from Ukraine) **& staff**	Information about Manily, Penzhinskaya Guba, local community and Geography.
	Manily	**Nikolay Giorgovich Smirnov, Director of Manily Port (from Petropavlovsk-Kamchatskiy)**	Provided tide tables for Cape Astronomicheski (-1hr from Manily), viewed hydrographic charts and discussed navigation, tides and tidal bores. Arranged possibility of trip on coal barge.

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	Manily	**Galina, Manily School Museum and History teacher**	
Tue 24th July	**Manily**		Meeting and talking with local people. Walk along coast around Manily.
Wed 25th July BARGE: Manily 0730 - Coal Mine 1130.			
	Penzhinskaya Guba coastline	**Met Feodor, Captain of the barge and staff at the coal mine.**	Walking approx. 4km along the coast east and west of the coal mine.
Thu 26th July BARGE: Coal Mine 0400 - Manily 0930			
	Manily	**Fishing & Hunting Inspector**	Discussions about fishing permits. Kamchatka Institute of Fisheries sometimes sends a boat for monitoring (mainly salmon).
Fri 27th July	**Manily & Penzhinskaya Guba**		Walked approx. 5km along the coast west of Manily
Sat 28th July SHIP 'Krashinenikov' Nikolay Ivanovich (Captain). Manily 0900d - Penzhinskaya Guba & Shelikova Bay. Good views of coastline, calm sea.			
Sun 29th July SHIP 'Krashinenikov': Sea of Okhotsk. Fog			
Mon 30th July SHIP 'Krashinenikov': Sea of Okhotsk. Fog & choppy sea.			
Tue 31st July SHIP 'Krashinenikov': Sea of Okhotsk. Cloudy but calming sea.			
Wed 1st Aug SHIP 'Krashinenikov': Pacific Ocean. Good views of coastline.			
Thu 2nd Aug - Arrived Petropavlovsk-Kamchatskiy 0200 - Yelisovo (by taxi)			
Fri 3rd August FLIGHT - Helicopter 'Aeroflot' Yelisovo 1300 - Nailichovo National Park 1400			
Fri 3rd August – Mon 6th Aug	Nailichovo National Park	Victor Michailovich Okrugin, Instutite of Vulcanology & Seismology, Academy of Sciences of the Russian Far East Division. Geographers, Geologists & Biologists from Moscow.	General interest - potential collaboration with Cardiff University School of Earth, Ocean & Planetary Sciences. Rest, relaxation, visits to hot springs and writing-up.
Tue 7th Aug FLIGHT - Helicopter 'Aeroflot' Nailichovo 1300 Yelisovo 1400			
Wed 8th Aug	**Petropavlovsk-Kamchatskiy**	**Olga Chernyagina & Vadim Kirichenko, Pacific Institute of Geography, Kamchatka Branch**	De-brief and agreement for further collaboration.
		Roman Kultaev & Dave Martin, Russian Far East Program Director, Pacific Salmon Centre, Portland, USA	Studying salmon rivers in Kamchatka for similar reasons i.e. to assess the character of a pristine ecosystem.
	Yelisovo	**Laura Williams, World Wide Fund for Nature (WWF) Kamchatka Regional Office**	
Thu 9th Aug FLIGHTS - International 'Aeroflot': Yelisovo 1300 - Moscow 1300. Moscow 2000 - London 2030			

Contact details for people met, as listed in the itineraries, are available from the author.

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C Outputs from the Fellowship

Report Title	Date	Author(s)
Managing Tidal Change Project Report for Phase 1	December 2006	Natasha Barker *in collaboration with* Maxine Westhead, Dept of Fisheries & Oceans Canada.
Managing Tidal Change Project Report for Phase 2	December 2007	Natasha Barker *in collaboration with* The Pacific Institute of Geography, Kamchatka Branch, Russia.
Managing Tidal Change Final Project Report to the Winston Churchill Memorial Trust	January 2008	Natasha Barker
Tidal Exploration – a film about Natasha Barkers' fellowship	In production.	Natasha Barker

The Project Reports are available on the Severn Estuary Partnership and Bay of Fundy Ecosystem Partnership websites and the Winston Churchill Memorial Trust website.

D Opportunities for Collaboration and Dissemination

Purpose	Audience / Location	Activity	Specific Objective		
			i) Flood Risk	ii) Tidal Power	ii) Public Marketing
Share experience and understanding of the influence of dynamic tides on coastal and river management	Severn Estuary	Information disseminated through the Severn Estuary Partnership's (SEP) *Severn Tidings* newsletter, *Severn Estuary Forum* and general media awareness around the Severn Estuary in England & Wales. See 'presentations' below.	Major	Major	Major
	Severn Estuary Bay of Fundy	Share information on engineering and habitat management options to alleviate coastal flood risk to people and the environment.	Major		
	Penzhinskaya Guba, Sea of Okhotsk	Assess the influence of the tide in an un-modified environment on habitats and the landscape.	Major		
	Bay of Fundy Severn Estuary	Obtain information on tidal energy to inform government policy and improve links with the renewables industry.		Major	
	Bay of Fundy Severn Estuary	Work with tourism officers to assess approaches to marketing highest tides and tidal bores.			Major
Contribution to a wider audience of coastal practitioners & professional development	Canada & UK	Explore Integrated Coastal Management & Governance progress. Share project reports with coastal & marine planners as detailed in Phase 1 report.			
	International (UK)	Royal Geographical Society/Institute of British Geographers Coastal & Marine Working Group session on 'Partnerships Delivering Integrated Coastal Management', September 2006 in London.			
	International (UK)	Member of the Organising Committee for the Institute of Civil Engineers International Coastal Conference, October 2007.			
	Europe	Board Member of CoastNET (UK coastal charity) and EUROCOAST 2001-2006; Council Member of EUCC-The Coastal Union 2006 onwards.			
Project dissemination.	International (Poland)	Poster on the 'Managing Tidal Change' project at the Littoral 06 conference in September 2006 in Poland.			
	Wales, UK	Institute of Civil Engineers Wales Branch, Severn Barrage conference 2007 – presentation on the role of the Severn Estuary Partnership and Bay of Fundy findings.			
	International (Russia)	Paper for the 8th International Scientific Conference 'Protection of Kamchatka's Biodiversity and Coastal Waters', November 2007.			
	International (UK)	Presentation of fellowship findings to Les Esturiales (network of European estuaries) meeting, Clevedon, UK - November 2007			
	South-West UK	Winston Churchill Memorial Trust South-West AGM, September 2007. Article for WCMT Newsletter, February 2007.			
	International (Canada)	Coastal Zone Canada 2008 poster 'Managing Tidal Change in Three Coastal Areas with the Highest Tidal Ranges, Vancouver, Canada, May 2008.			
	Bristol, UK	Presentation on Estuary Management to Soroptemists Society, Bristol, UK, July 2008			
Education	UK	Lectures on the Marine Geography degree course at Cardiff University, 2006 & 2007.			

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E Post-trip Contacts

CONTACT NAME	ORGANISATION	LOCATION	NOTES	FOLLOW UP
Simon Winchcombe	BBC – Producer	London	Contact via Martha Masden	Sent 'top pics' and Kamchatka videos. Offered assistance with the planning of a trip to Kamchatka in 2008 for the series 'Last Man Standing'.
Ami Vitale	National Geographic – Photographer	Washington	Met in Yelisovo and travelled to Tilichiki together.	Sent all photos & videos on DVD plus Kamchatka videos. Possible inclusion of pictures in National Geographic 2008-09.
Stuart Judd	Coastal Ways - Programme Contact		Emailed press release and further information.	Send final reports - possible input to television series
Natalie Hoare	Geographical Journal - Features Editor	London	Emailed press release and further information.	Send final reports - possible article

Publicity for the research will be pursued on completion of the Phase 1 & 2 reports during 2008.

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F Post Project Notes

The opportunity provided through the fellowship to visit such a remote and unspoilt part of the world is of huge value to a geographer. Witnessing an untamed wilderness, a land where people have little influence on the landscape and wildlife, highlights the extent to which Britain has become extremely developed.

Comparing three large dynamic estuaries experiencing some of the highest tidal ranges in the world is a unique area of research which has the potential for further exploration, physically and academically! Experiencing the contrast of an estuary in the wilderness, compared to the relatively urbanised Severn Estuary raises questions about the level of development which is acceptable to different people. Setting environmental limits and deciding what an acceptable quality of life is, are key issues raised by this research. With estuaries as the common ground, the project illustrated the contrasts between society in a Far Eastern post-Soviet wilderness world and a highly developed western capitalistic society. It was a rare privilege to obtain this perspective, particularly at a time when major new development is being considered at a national level for harnessing the renewable energy potential from the tidal range of the Severn Estuary.

At the time of writing it is not possible to predict all the benefits which will come from the fellowship. The reports will be disseminated in my professional field and may lead to further publications, exchange of information and perspectives. From a personal perspective, the visit to Penzhinskaya Guba alongside the Bay of Fundy and my ongoing work for UK estuaries, has initiated a new level of thinking about sustainable estuary management…how can we better define it, what baseline should we use, what targets should we set?

Experiencing the total wilderness of Kamchatka was like a window into the history of an undeveloped Britain. This will provide stronger possibilities to understand where we have come from, where we are heading…and ultimately give us a better chance of finding a sustainable level of human activity.

Though sharing common ground over estuaries and tides, the travelling fellowship revealed cultural differences which have a significant bearing on the challenge to achieve sustainable management.

On board the 'Krashinenikov' in the Sea of Okhotsk, travelling between Manily & Petropavlovsk-Kamchatskiy in Kamchatka.

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