I am pleased to present on behalf of myself and Mike.
The two projects I’m going to talk about resulted from highway works along the shores of major salmon-producing rivers. Our Canadian Department of Fisheries and Oceans has a long-standing policy of No Net Loss regarding salmon habitat – both of these cases the highway footprint intruded on inter-tidal sedge meadows which had to be compensated for.

This talk has a biological focus. If you want to know more about the physical aspects of this work feel free to talk to Mike who is in the audience.

In terms of basic design, we tried to re-create the conditions of the pre-existing marshes. There was no data or money for modeling.

The Skeena River Project was located on the river’s north bank some 40 km west of Prince Rupert and was built in 1988 – 1990.

The Nass River Project was on the Nass River’s north bank some 20 km east of Gingolx and was built in 2002.

Both projects are tidal – with tide ranges of 6 – 7 m (20 – 23 ft). Both rivers have a double freshet; from snow melt in May/June and from fall rains in Sept/Oct. And both carry significant sediment loads.
I’ll talk about the Skeena River project first.
This is a view of the Skeena project area that affected inter-tidal vegetation.

Development of the concept & design was done by me, Mike and Dr. Rolf Kellerhals.

There was no source of fill, so the project was designed to facilitate habitat creation through sediment accretion – we used spurs to promote localized sediment accumulation. This is a photograph of the whole project area. I'm only going to talk about the eastern most site.
This is a schematic of the completed works at the main compensation site.

We’ll now look at a series of photographs taken from the offshore tip of the short central rock spur. These are the same view, taken from the same place in mid-July on subsequent years. I’m going to leave each one up for about 10 seconds or so. The point is for you to see is the overall change from year to year – not a whole lot of details from each photograph.
This is what it looked like off the end of the short spur in the first summer after completion. The vegetation visible near river was pre-existing.

There are occasional shoots in the placed material – some of the fill material used was taken from places which had inter-tidal vegetation growing on them, so these are not signs of natural re-establishment of vegetation on bare ground, pre se.

The base elevation of the channel in the foreground is -1.38 m.
The is the 2nd year after construction. The base elevation of the foreground channel trough is -0.72 m.
There are now small colonies of vegetation appearing on mud flats inshore of pre-existing vegetation and the foreground channel is almost gone. The elevation in the channel remnant is -0.65 m; more than a meter higher than last year.

At this point I’ll say a quick word about the sedge life cycle. It is root driven. The established plants set seed in mid/late July. Shortly thereafter most of the above ground biomass is mobilized and trans-located to underground roots & rhizomes. At this time, the root system expands and the colony produces over-wintering shoots. These shoots are about 5 cm (2”) high above the mud surface and remain dormant until spring – when the colony remobilizes the stored biomass and uses it for above ground growth.

There are two important points that result from this:

1) the colony needs to build up root mass before it can expand – single shoots (i.e. the first year’s growth from a germinated seed) are susceptible to washout; it takes about 3 years before the colony has the root mass to expand; and a couple more years before it is able to withstand erosive forces.

2) the overwintering shoots sit at ground level through the fall and winter. If enough sediment is deposited over them during fall freshet then they will suffocate in the spring – and the colony dies.
5 years after construction – there are now substantial sedge colonies where there were scattered shoots.

The foreground drainage channel is now filled in. The substrate elevation where the channel was is 0.22 m – an increase of 1.6 m.
14 years after construction – there is now something approaching a sedge meadow.

We no longer have survey data so we don’t know the magnitude of the surface elevation changes.
We will now look at photographs taken from the toe of the long, eastern most rock spur – marked by the blue triangle.
The “fingers” of sedge extending downslope of the outer edge of the vegetation result from erosion of deposited (and suffocating) sediment being washed away by surface erosion – allowing the over-wintering shoots to survive.

There are three colonies more-or-less in a row, offshore of the remnant marsh. These are test plots from 1990.
Only the two test plots closest to the rock spur remain – the third has been buried.
The substrate elevation out front of the marsh has increased from 0.52 m in 1989 to 0.67 m in 1991. There has been some loss of marsh in the foreground.

The previous set of photographs was taken from the offshore tip of the rock spur in the distance. 1991 was the year that small colonies of sedge appeared in front of the spur and when the channel around the end of that spur was pretty much filled.
All the remnant marsh along the road shoulder is now buried – this is 7 years after construction. The elevation at the toe-of-slope is 2.12 m – an increase of almost a meter from 1991.

Parts of the remaining two test plots are still visible.

There is a relatively thick layer of bark mulch over laying the substrate in the foreground – on which nothing is growing.

This is the year when substantial sedge colonies were observed offshore of the short spur in the center of the photo.
Note the large area of bark mulch in the foreground. The bright green visible in the middle distance is duckweed.
Sedge colony development in the center of the site is now in full swing.
Sedge meadow is now more-or-less continuous throughout the center of the site.

There are scattered shoots and small colonies becoming established in mid-foreground – and some duckweed on the bark mulch.
We’ll now look at the site from the air.

This is 2 years after construction. Mike’s analysis of the surface elevation data showed that 4,000 m$^3$ was deposited on the site in the first year and another 60,000 m$^3$ between July 1990 and July 1994.
Remnant along-shore vegetation in the central and western parts of the site are now gone.

There are now scattered colonies appearing inshore of the pre-existing vegetated offshore bar, and to either side of the prominent drainage channel in the western part of the site.

Mike’s analysis of the surface elevation data shows that there has been over 100,000 m³ of sediment deposited in the site between 1989 and 1996 – an average annual deposition of 15,000 m³.
The reason for the yellow outline is that the vegetated area determination was now being done by mapping vegetation polygons over aerial photographs, rather than ground surveys. This means that we no longer have surface elevation data and, ergo, can’t determine quantitative changes to sedimentation rates and such.

At this point, there is no budget for any further work on this site and I piggybacked this work on the Nass monitoring – on my own nickel (although highways paid for the helicopter).

This is 13 years after construction. There are now many vegetation colonies established inshore of vegetated bar, in the downstream part of the site and upstream of the long spur.
One year on.
2006 - The vegetation inshore of pre-existing bar/island is now pretty much continuous and there are more colonies on both the eastern and western parts of the site.
The vegetation in the central part of the site is now continuous over the outer part of the site. There are extensive areas approaching continuous coverage on both the eastern and western parts of the site.

There is still no perennial vegetation immediately adjacent to road shoulder in the central part of the site.
so – success or failure? In terms of meeting the No Net Loss criteria:

- Compensation works completed in 1989.
- There were overall losses of vegetation within the site until 1999.
- It was 14 years before the vegetated area increased above baseline (2002).
- Those increases in vegetated area only occurred after the site achieved stable equilibrium in the fluvial environment.
- In 2011 (22 years after the impacts were incurred) the vegetated area on site was 3 times the pre-existing area.

Lessons learned:
- The substrate/habitat must be stable in order for perennial inter-tidal vegetation to grow.
- Inter-tidal sedge colonies do not expand until a substantial root mass is built up – 3 to 4 years for a seedling.
Now we’ll look at the Nass River project. Mike and I did the design work in 1999 – about the time that the Kyhex-tyee were finally starting to grow vegetation.

With that experience in mind, we established three design principles:
Clearly, works undertaken where there is pre-existing vegetation have the potential to negatively impact that vegetation – should the works induce sediment deposition.

Within the Nass project area, there was an area where there was mud/sand flats with very little pre-existing inter-tidal and we located the compensation works there.
Our concept was to pre-build platforms, onto which salvaged vegetation would be transplanted. The constructed platforms would be designed so that they would be more-or-less in equilibrium within the fluvial environment from the get go.

The platforms were built with pit run material – that included gravel, cobble and boulders. The fill would be contained by a perimeter rip-rap dyke which would be topped with oversize (i.e. 2+ m) rocks.

The elevations and slopes of the platforms mimicked adjacent inter-tidal vegetated meadows.
Using vegetation salvaged from within the highway impact footprint is inherently challenging and logistically problematic:

1) working in the inter-tidal zone means that you can only work when the tide is out. The tides on our coast are mixed semi-diurnal – there are two lows between two highs daily. There are ~5 or 6 workable hours in every 10-12 and operating on a set schedule doesn’t work.

2) There’s no road – so getting the vegetation mats from the source to the platform is a problem. In this case, they used barges. On each low tide: vegetation mats were salvaged and loaded onto one barge while the other was being offloaded and the mats planted. During high tide a tugboat would switch the barges.

3) The good news is that because we were working from within the impact footprint we could take BIG mats – 2m x 1m and ~ half a meter thick. They were taken with an excavator. The transport from barge to planting site was via front end loader. The receiving excavator dug an appropriate hole then the loader laid the mat into it – then excavator back filled around the sides.
Design Principles:

1. Do no further harm
2. Platforms built to be stable
3. Platforms stocked with salvaged vegetation
This shows the compensation platforms in the first year after construction. The shoreline length visible in this photograph is about 800 m and the two platforms have a surface area of about 40 000 m². The protective ring dyke is clearly visible. The small fan under blue arrow was pre-existing and used to provide elevation data (among other marshes).

We’ll now look at a series of ground photos taken from the west end of the east platform (the blue arrow). As before these are the same view, taken from the same place and taken in mid-July on subsequent years.
This is the first summer after construction and planting.

The construction, salvage and planting were all done in one go. Starting in mid-March and finishing at the end of April. Towards the end, the sedge was in full spring growth and there were 30 -50 cm shoots present on the vegetation sedge mats. The mats were taken and planted within 12 hours – as the whole plant structure was moved en masse there was little or no observable growth set-back from the move.

The red letters reference the same features in the following photos.

The vegetation in the right foreground was pre-existing, as is the colony @ f. In this photo you can clearly see the the ring dyke and boulder barricade (for protection from ice push and wave action).
3 years later and we’re pretty close to continuous cover.
Now we’ll look at the changes from the air – this immediately after construction.
This is the 2nd summer after construction and transplanting.
From the ground, it appeared that the vegetation coverage was close to continuous.

From the air, you can still see bare ground between some of the mats.
Now we’re getting continuous coverage in same parts of the platforms.
There is now more continuous than discontinuous vegetation on the platforms.
Area mapping shows that the vegetation coverage started to increase from the time of planting and continued on a fairly even pace since then. The rate of increase slowed down a tad after the first few years.

So, to compare the two projects:

- the Nass project “grew” vegetation sooner and more consistently than did the Skeena works.
- however, there was much more effort – in terms of construction time and money – put into the Nass compensation works than was put into Skeena works.
Lessons Learned:

1: inter-tidal vegetation is vulnerable to impacts from fluvial processes – especially fall sedimentation, wave erosion and ice action.

2: substrate must be stable in order for inter-tidal vegetation to flourish.

3: transplanted inter-tidal vegetation must include all the roots and rhizomes.

4: size matters: large mats of vegetation can withstand wave erosion and/or washout whereas small plugs cannot.

5: working in the inter-tidal is logistically challenging – detailed planning is vital.

6: These projects take time – the sedge colonies do not colonize bare ground quickly. The Nass works took 12 years to achieve the criteria for success and the Kyhax-Tyee works took over 20 years.

On point 6 – these projects are done under legal agreements with specified monitoring. Generally, these are much too short.
On behalf of myself and Mike:

Thank You