Comments on the Pacific NorthWest LNG Environmental Impact Statement and Environmental Assessment Certificate Application

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(supported by the Prince Rupert Environmental Society, the T. Buck Suzuki Foundation, and the United Fishermen and Allied Workers Union - UNIFOR)

Author's Note: *Although it is generally accepted stylistic practice to write objective scientific critiques in the third person, I am taking the liberty of using the first person in this critique under certain circumstances based on the following rationale. The proponent has frequently referenced papers that I have authored, and, in some cases, has used information from those papers to support specific actions and assumptions. While I appreciate appropriate recognition of my scientific work, it was by no means the intent of this work to support applications involving the degradation and/or destruction of eelgrass beds in the Chatham Sound region (including the Skeena River estuary and Prince Rupert Harbour). To avoid the continued awkwardness of referring to myself in the third person, I will use the first person when referring to my own work, and in explaining the rationale and significance of that work. I have also been involved in recent studies around the area, some of which are in press at this moment, and will use the first person when referring to these.*

To avoid confusion, references to citations and figures have been removed from material quoted directly from the proponents reports. All figure and citation references in this critique refer to information provided in this critique, and not that provided by the proponent.

1. Flora Bank Eelgrass Assessment

The proponent carried out a number of eelgrass surveys on Flora Bank in an attempt to determine the areal extent of the eelgrass bed:

> *Owing to the importance of Flora Bank as salmon rearing habitat, several methods were used to estimate, triangulate and ground-truth eelgrass extent and composition across this area. The extent of eelgrass was estimated by circumnavigating the bank with a hand-held GPS unit. These surveys were supplemented by assessing conditions on transects running perpendicular to the slope of the bank, from subtidal to intertidal zones, along which the first (i.e., deepest) observation of eelgrass was noted. In addition, eelgrass shoot percent cover and canopy height were estimated in 0.5 m x 0.5 m quadrats distributed across the Bank in a stratified random manner. These field surveys were supplemented by analysis of satellite imagery acquired in 2011 to further estimate the distribution of eelgrass across the Bank. These estimated distributions were compared to previous remote-sensing estimates to obtain insight into interannual variability in the extent of this important eelgrass area.* (EIS, Section 13 - Marine Resources, pg. 13-13)

Each of these surveys is described in further detail in Appendix M1 of the EIS. Initially, a subtidal delineation was done during May 29-31, 2013, as follows:

> *Between May 29 and 31, 2013 a towed video survey was conducted from a small aluminum skiff (6.67 m in length) with a shallow draft.*
>
> *Twenty underwater video transects haphazardly spaced along the circumference of Flora Bank were surveyed using an underwater camera (Deep Blue Pro Splash Cam, Ocean Systems Inc., Everett, WA, USA) mounted on a polyvinyl chloride (PVC) frame attached to a 0.5 m x 0.5 m quadrat.*

> *To visualize eelgrass in the highly turbid water, the camera frame was tipped onto its side and towed rear-facing to ensure imagery would be collected from within the eelgrass canopy. Transects began in subtidal depths adjacent to Flora Bank in water depths assumed to be beyond eelgrass depth distribution limits. Attempts were made to collect transect data every 250 m along the circumference of Flora Bank; however, this was not possible due to the water current velocity laterally displacing the research vessel and poor underwater visibility due to high water column turbidity. The camera was towed towards Flora Bank (perpendicular to the hypothesized eelgrass bed edge) at a constant speed (not exceeding 4.5 km/h, speed over ground). Transects were halted and a GPS waypoint recorded upon visual confirmation of suspected eelgrass shoots on the video monitor. All video imagery collected during the survey was reviewed by a Stantec marine scientist with extensive eelgrass experience to verify field determinations of eelgrass presence/absence. Depth data were not recorded during the survey due to a chart plotter malfunction. All references to depth in this report are taken from Canadian Hydrographic Service (CHS) chart soundings.* (EIS, Appendix M1 - Technical Data Report - Marine Resources, pg. 64-65)

> *While reductions in water clarity were anticipated, it was not expected that the turbidity levels would preclude the ability to visualize the quadrat frame on the drop camera. Multiple unsuccessful attempts were made to collect downward-viewing images of the substrate at varying locations during all tidal stages throughout the survey. As a result, the sampling method was amended as described.* (EIS, Appendix M1 - Technical Data Report - Marine Resources, pg. 69)

Clearly, this was a very difficult survey for the proponent, with issues such as high water column turbidity, high water current velocity, and chart plotter malfunction all mentioned as contributing factors. The sampling method amendment of towing the camera frame sideways to collect rear-facing imagery is a particularly unusual technique. Not only does it involve dragging the camera frame through the eelgrass bed, a very damaging procedure and one generally avoided by most scientists working in the field, but it also precludes accurate field of view measurements, and thus density calculations, since the reference frame is now at an angle to viewed eelgrass. Since it has been well reported that visibility conditions within the Skeena River plume (including Flora Bank) often require camera towing altitudes of less than1 m above the bottom (Faggetter 2009a, 2009b, 2011a), it is very surprising that the proponent attempted the subtidal survey with a camera mounted on 1 m tall frame. Based on this survey, the proponent estimated the areal coverage of eelgrass on Flora Bank at 2.00 km^2 (EIS, Appendix M1 - Technical Data Report - Marine Resources, pg. 72)

On May 30, 2013, an intertidal delineation of eelgrass on Flora Bank was carried out as follows:

> *On May 30, 2013 the intertidal extent of Flora Bank was surveyed during low tide. Two field biologists equipped with dry suits disembarked the research vessel on the eastern edge of Flora Bank approximately 30 minutes before low tide. With GPS units on tracking, each biologist walked in separate directions along the perimeter of Flora Bank. Efforts were made to walk along the seaward edge of the deepest visible eelgrass shoots encountered.* (EIS, Appendix M1 - Technical Data Report - Marine Resources, pg. 65)

Again, it appeared that this survey was not completely successful, as the field biologists were unable to travel the complete circumference of Flora Bank (see EIS, Appendix M2 - Technical Data Report - Marine Resources Maps), leaving a large gap on the northwest side of Flora Bank. Since this is the region of the eelgrass bed which is closest to the proposed trestle, this data gap contributes to a lack of sufficient information on which to make informed decisions on eelgrass impact. However, the proponent estimates the areal coverage of eelgrass on Flora Bank based on this survey at 1.74 km^2 (EIS, Appendix M1 - Technical Data Report - Marine Resources, pg. 72).

Finally, the proponent attempted to use satellite data to determine the areal extent of the eelgrass on Flora Bank as follows:

> *To obtain satellite imagery of Flora Bank, multiple options were explored to provide the best data interpretation possible given the dynamic environment of Chatham Sound.*

> *Prior to commencing field surveys, a WorldView-2 satellite test image (collected on June 7, 2011) was acquired through the DigitalGlobe image archive to assess whether satellite imagery would be useful for eelgrass classification in this region. Although the image coverage did not extend south beyond the Kitson Islet just north of Kitson Island, the image coincided with a low tide and all of Flora Bank was exposed.*
>
> *Coinciding with the 2013 field surveys, both the WorldView-2 and Pléiades satellites were commissioned through BlackBridge Geomatics to increase the probability of obtaining useful satellite imagery of Flora Bank ... During the study period, two WorldView-2 satellite passes were possible on May 24 and 26, 2013 at low tides of 0.4 m and 0.2 m, respectively. Three Pléiades satellite passes were made at low tides on the May 24, 26 and 28 of, 2013, at predicted tidal heights of 0.4, 0.2 and 0.4 m respectively. Due to adverse weather conditions on these days (i.e., the cloud cover was greater than 70%) and no usable satellite imagery from either satellite was acquired. However, BlackBridge Geomatics continued to collect Pléiades imagery for the Project after these dates. Although the low tide was higher than preferred (1.5 m), a cloud free image was acquired on June 1, 2013, and one day after the field surveys were completed.* (EIS, Appendix M1 - Technical Data Report - Marine Resources, pg. 66)

Presence/absence of eelgrass in the satellite images was determined by applying both supervised (WorldView-2 satellite image) and unsupervised (Pléiades satellite image) maximum likelihood classification (EIS, Appendix M1 - Technical Data Report - Marine Resources, pg. 67, 74-75). The Pléiades satellite image suffered from "*high turbidity*" and had "*large areas for which there was little information due to the suspended sediment*" (EIS, Appendix M1 - Technical Data Report - Marine Resources, pg. 74). Based on these two satellite images, the proponent estimated the areal coverage of eelgrass on Flora Bank at 0.33 km^2 from the Pléiades image (EIS, Appendix M1 - Technical Data Report - Marine Resources, pg. 74) and 0.64 km^2 from the WorldView-2 image (EIS, Appendix M1 - Technical Data Report - Marine Resources, pg. 75). The proponent goes on to say that "*direct comparison of both satellite images demonstrated a 64.7% overlap of areas*" and that "*both images delineated large eelgrass patches in the northern and eastern regions of Flora Bank*" (EIS, Appendix M1 - Technical Data Report - Marine Resources, pg. 75). Furthermore, they conclude "*Based on this level of agreement between images, it was assumed the 2013 field data would provide a reasonable approximation of the extent and structure of Flora Bank eelgrass described by the 2011 WorldView-2 imagery*" (EIS, Appendix M1 - Technical Data Report - Marine Resources, pg. 75).

In summary, the proponent has used a range of survey methods to estimate the areal extent of eelgrass on Flora Bank, generating values ranging from 0.33 km^2 to 2.00 km^2. There is a wide degree of variation between the results of their different survey methods, and all of the survey methods used during the field season of 2013 were subject to significant technical difficulties, as described above. Ultimately, the proponent settled on a value of 0.64 km^2 derived from a WorldView-2 satellite test image collected on June 7, 2011, rather than on data collected during 2013. Using this data, the proponent then goes on to estimate the amount of eelgrass that will be destroyed by the marine terminal and breakwaters at 935 m^2 (EIS, Section 13 - Marine Resources, pg. 13-36). The issues associated with the proponents survey methods, and the variability of their data, suggests that the accuracy of their estimate of eelgrass impacted by the project is also likely to be poor. The proponent explains their data variability as follows:

> *Borstad Associates Ltd. completed a compact airborne spectrographic imager (CASI) survey of the greater Prince Rupert Harbour, including Flora Bank. Their August 1997 survey estimated the areal coverage of Flora Bank eelgrass to be 0.8 km^2. This value is comparable to our 0.64 km^2 estimate based on June 2011 imagery. While both values are very similar in magnitude, this 21% difference in areal estimates may be the result of multiple factors including: comparison of differing methodologies (airborne CASI vs. WorldView-2 satellite); intra-annual variation; and/or interannual variation.*
>
> *Eelgrass above-ground biomass and spatial distribution follows a strong seasonal pattern with minimal growth rates found during periods of low light and temperature in fall and winter with subsequently increasing growth rates during spring progressing to maximum distributional extent and above-ground biomass levels in early to mid-summer periods.*

> *As the Borstad Associates Ltd. CASI survey was collected during August, as opposed to our WorldView-2 survey in early June, it is possible our data do not accurately reflect the maximum intra-annual spatial distribution of Flora Bank eelgrass.*
>
> *Substantial inter-annual variation in eelgrass bed coverage has been observed in multiple studies at various locations throughout North America. … Given the magnitude of inter-annual variation recorded from eelgrass, our observed 21% difference from the results of Borstad Associates Ltd. is not likely to be of biological relevance. Further, the agreement of total areal extent values combined with the observed similarity in the distributional pattern of eelgrass between our survey and the Borstad Associates Ltd. survey 14 years prior suggests that the distribution of Flora Bank eelgrass has been relatively stable over this time period. In terms of the specific distributional pattern, two contrasting areas were apparent upon visual comparison of both surveys. First, a large patch of eelgrass present to the northeast of Kitson Island in 1997 no longer exists. Alternatively, the 2011 satellite imagery showed a bed of eelgrass along the southwestern aspect of Lelu Island near Leer Point which was not detected in the Borstad Associates Ltd. survey. These distributional shifts highlight the dynamic nature of submerged aquatic vegetation distributions in coastal environments.* (EIS, Appendix M1 - Technical Data Report - Marine Resources, pg. 76-77)

While it is true that eelgrass has significant inter- and intra-annual variations, this is not justification to conclude that "*our observed 21% difference from the results of Borstad Associates Ltd. is not likely to be of biological relevance*" (EIS, Appendix M1 - Technical Data Report - Marine Resources, pg. 77), nor is it justification to imply that no eelgrass is present underneath the proposed trestle simply because it was not seen on the 2011 WorldView-2 satellite. In fact, the highly variable nature of the eelgrass extent, particularly the intra-annual variation, is a good reason to suspect that the proponents did not observe eelgrass growing at the edge of Flora Bank simply because they were looking at the wrong time of the year. Seasonal studies at nearby Lucy Islands (Faggetter 2011c) showed that eelgrass areal extent was greatest in mid-July. A study on the growth and nitrogen uptake by eelgrass in a homogeneous bed located in the Oresund approximately 10 km north of Copenhagen (latitude 55° 40' N) showed that maximum eelgrass biomass was reached in August and minimum biomass was found in April (Pedersen and Borum, 1993). Although this study took place in the Atlantic, it was at a similar latitude to Prince Rupert (54° 19' N), and thus probably reflects the seasonal patterns observed here. Even though the proponents recognize the seasonal issues in their statement "*As the Borstad Associates Ltd. CASI survey was collected during August, as opposed to our WorldView-2 survey in early June, it is possible our data do not accurately reflect the maximum intra-annual spatial distribution of Flora Bank eelgrass.*" (EIS, Appendix M1 - Technical Data Report - Marine Resources, pg. 77), they do not recognize that their low estimate of impacted eelgrass may in fact be the result of this seasonal variation, and that if they had, in fact, surveyed in August, there may well have been eelgrass present below the trestle.

A further examination of previous surveys of Flora Bank is merited. Figure 1 shows an overlay of the data from the Borstad Associates Ltd. CASI survey done in 1997 (Borstad Associates Ltd. 1996, Forsyth *et al.* 1998) on the proponents' data. The total areal extent of the eelgrass from this survey, as calculated by myself (Faggetter 2009b), was 0.8 km^2. Of particular note are the eelgrass patches that extend along and under the proposed trestle. These patches do not appear in the proponents' data. In 2009, I surveyed eelgrass on Flora Bank (Faggetter 2009b). This data is shown in Figure 2 overlaid on the proponents' data. As with the proponents' surveys, this data was collected during May, and does not represent the annual maximum extent of eelgrass for the area. However, while this survey was quite limited in nature, it illustrates two important factors: (1) using a methodology designed to be effective under low visibility, high current situations, eelgrass was observed subtidally, in several cases beyond the perimeter defined by the proponents' subtidal delineation; and (2) eelgrass was observed below the proposed trestle location.

On June 24, 2013, an independent group of scientists and technicians, myself included, performed a low altitude aerial survey of Flora Bank. The date was specifically chosen to coincide with a 0 m low tide (unlike the June 7, 2011 WorldView-2 satellite image, which was taken on a 1.3 m low tide). A 0 m low tide ensured maximum eelgrass bed exposure for aerial photography. Photographs from this flight were rectified, georeferenced, and mosaiced to form a complete image of Flora Bank (see Figure 3). Due to the variation in the angle of lighting as a result of photographs taken from multiple positions and altitudes, it was not possible to carry out a maximum likelihood classification. However, as a person with significant experience in both eelgrass surveys and remote sensing technology, I was readily able to identify the eelgrass based on color and texture, and hand digitized the patches (see Figure 4). No attempt was made to differentiate the eelgrass patches based on density. It was clear from the photo that eelgrass on the outer edges of Flora Bank had not yet reached its maximum growth for the season (e.g., the eelgrass was still short and "shrubby", rather than forming long, flat-laying swaths). This is not unexpected, as the eelgrass on the outer edges occurs at greater depths and receives less total sunlight annually, thus reaches its maximum growth later than eelgrass at the center of the bank. Based on this data, I estimated the total areal extent of the Flora Bank eelgrass bed at 1.0 km^2. As with the proponents' data, this estimate does not likely represent the maximum extent, which would occur later in August. However, it is still significantly larger (56%) than the amount (0.64 km^2) used by the proponent in their report (see Figure 5). The extent of the eelgrass seen in this survey also agrees well with the Borstad Associates Ltd. CASI survey done in 1997 (Borstad Associates Ltd. 1996, Forsyth *et al.* 1998; see Figure 6). Of particular note, the large patch of eelgrass present to the northeast of Kitson Island in 1997, which did not appear in the 2011 WorldView-2 satellite image, is present in the 2013 aerial survey. However, the 2013 aerial survey was not able to confirm the presence of the bed of eelgrass along the southwestern aspect of Lelu Island near Leer Point, which was detected in 2011 WorldView-2 satellite image, due to lack of coverage at this location. Finally, it is important to note that there is eelgrass present under the proposed trestle based on the data from the 2013 aerial survey (see Figure 7). The amount of this impacted eelgrass is 14,295 m^2 - approximately 15 times more than the proponents' estimated 935 m^2.

It is clear that the proponent has chosen to use an areal extent for the Flora Bank eelgrass bed that significantly underestimates the amount of eelgrass present as compared to other surveys of the region. This is of importance to evaluating the overall impact of the proposed project for several reasons:

1) Significant patches of eelgrass growing in the area of the proposed trestle were missed by the proponents' surveys. This eelgrass will be severely impacted by the project and needs to be included in the discussion on impacts and mitigation.
2) According to the proponent:

    "*The final HOP* [habitat offsetting plan] *will include detailed design drawings and construction plans for habitat offsetting measures. Once the final offsetting features have been selected, offsetting ratios will be developed in consultation with DFO. These ratios will reflect both the ecological value of affected habitats and the type of permanent alteration or destruction of fish habitat incurred. Specifically, ratios will be higher for habitats that have high ecological value and productivity and lower for habitats that have lesser value as fish habitat*." (EIS, Appendix K - Conceptual Fish Habitat Offsetting Strategy, pg. iii)

    Thus, for the purpose of making decisions on how much new eelgrass habitat must be created as part of a habitat offsetting plan, it is important to have an accurate estimate of the current extent of impacted eelgrass, as well as a clear understanding of the ecological value of the habitat provided by that eelgrass. Compensation ratios for eelgrass habitat generally range from 2:1 to 4:1, depending on the ecological value of the destroyed habitat and the degree of uncertainty in the viability of the offsetting plan (Pearson *et al.* 2005, Sikumiut Environmental Management Ltd. 2011). Due to the importance of eelgrass habitat, DFO recommends a compensation ratio of at least 3:1 (DFO 2006).
3) Given the marked intra-annual variations of eelgrass (Faggetter 2011c), the precautionary principle, which guides Canada's environmental policy, should be followed. In this case, that would imply using the maximum recently recorded bed size (e.g., the Borstad data backed up with recent supportive aerial photos) to estimate amount of eelgrass impacted by the proposed project.

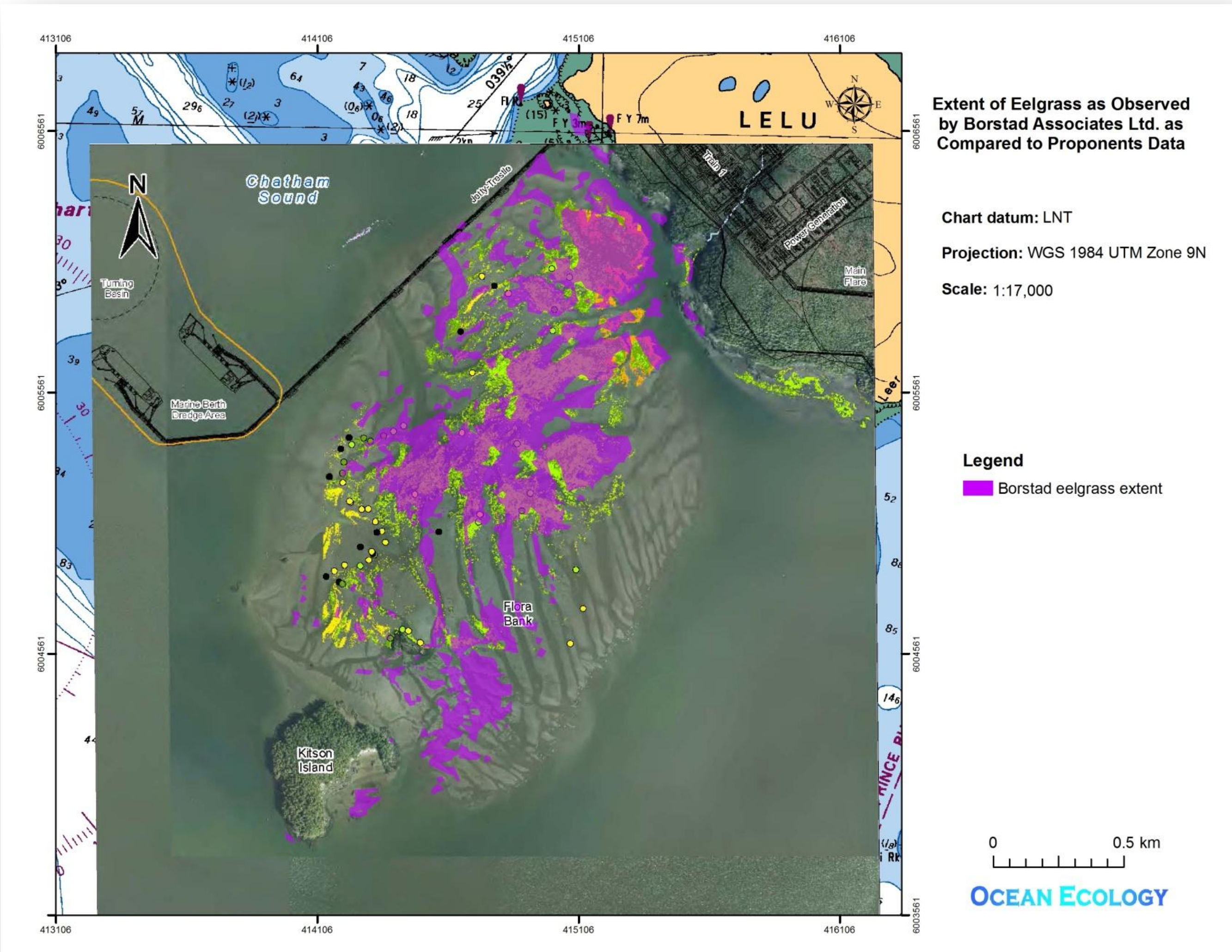

Figure 1. Extent of eelgrass as observed by Borstad Associates Ltd. as compared to the proponents' data.

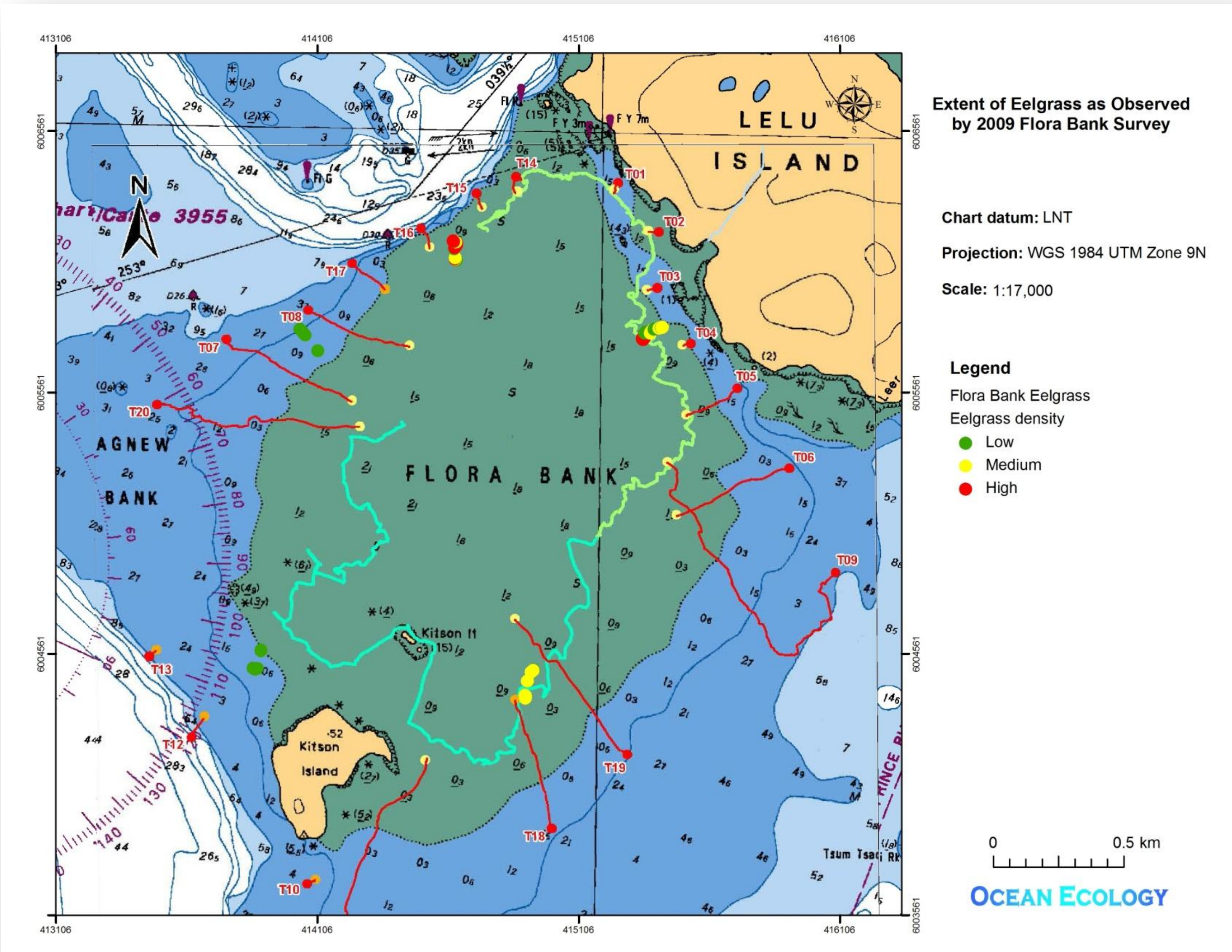

Figure 2. Extent of eelgrass as observed by the 2009 Flora Bank survey as compared to the proponents' data.

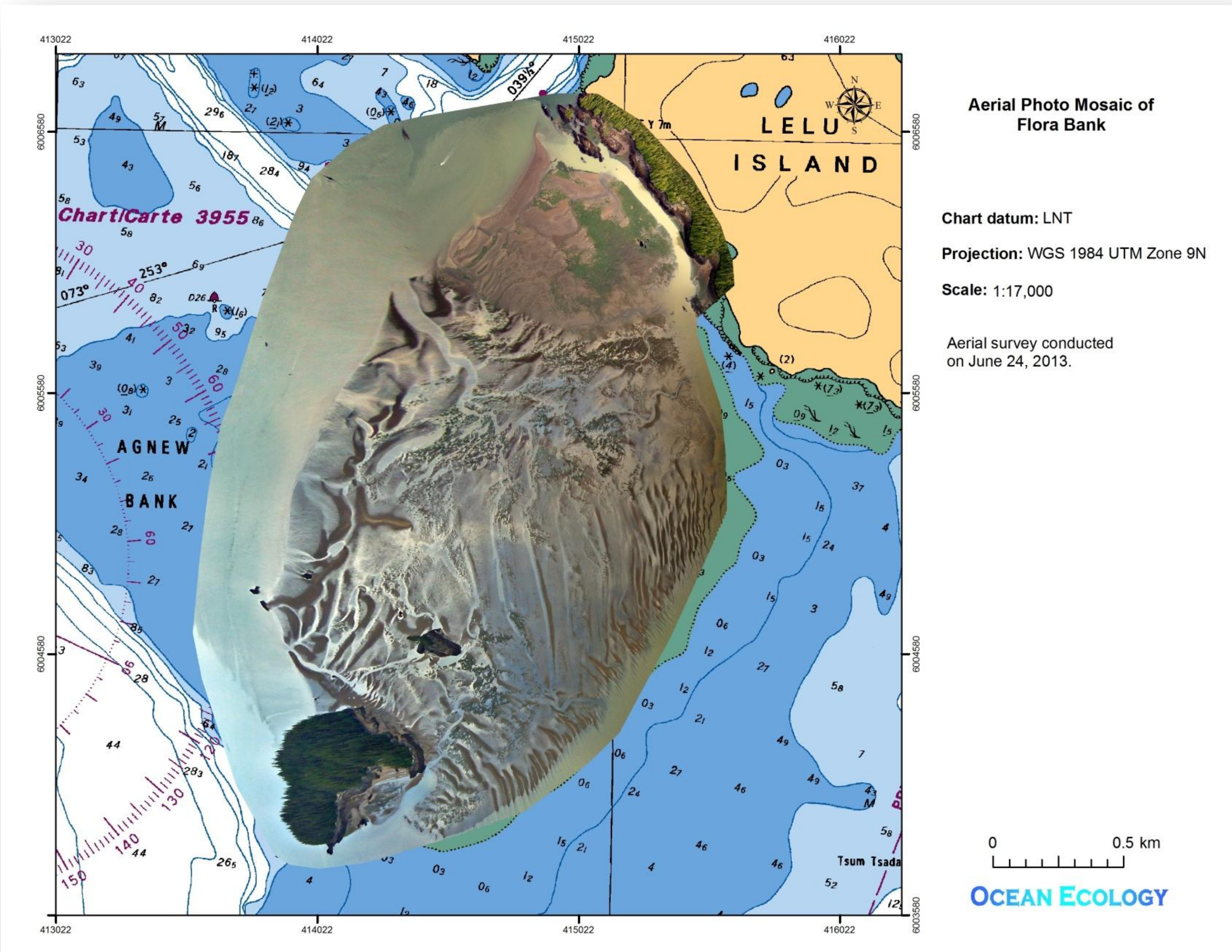

Figure 3. Aerial photo mosaic of Flora Bank from aerial survey conducted on June 24, 2013.

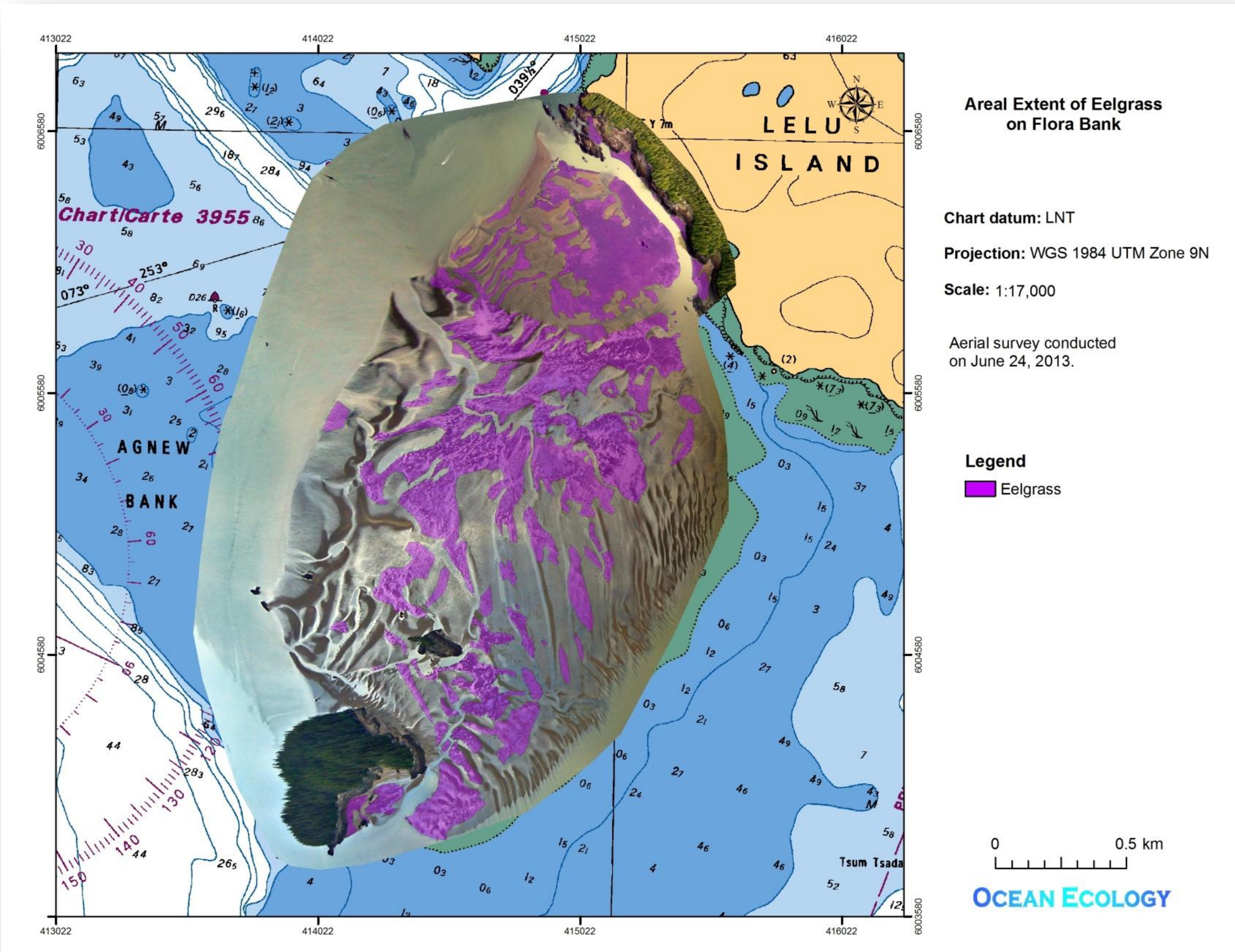

Figure 4. Areal extent of eelgrass on Flora Bank based on the aerial survey conducted on June 24, 2013.

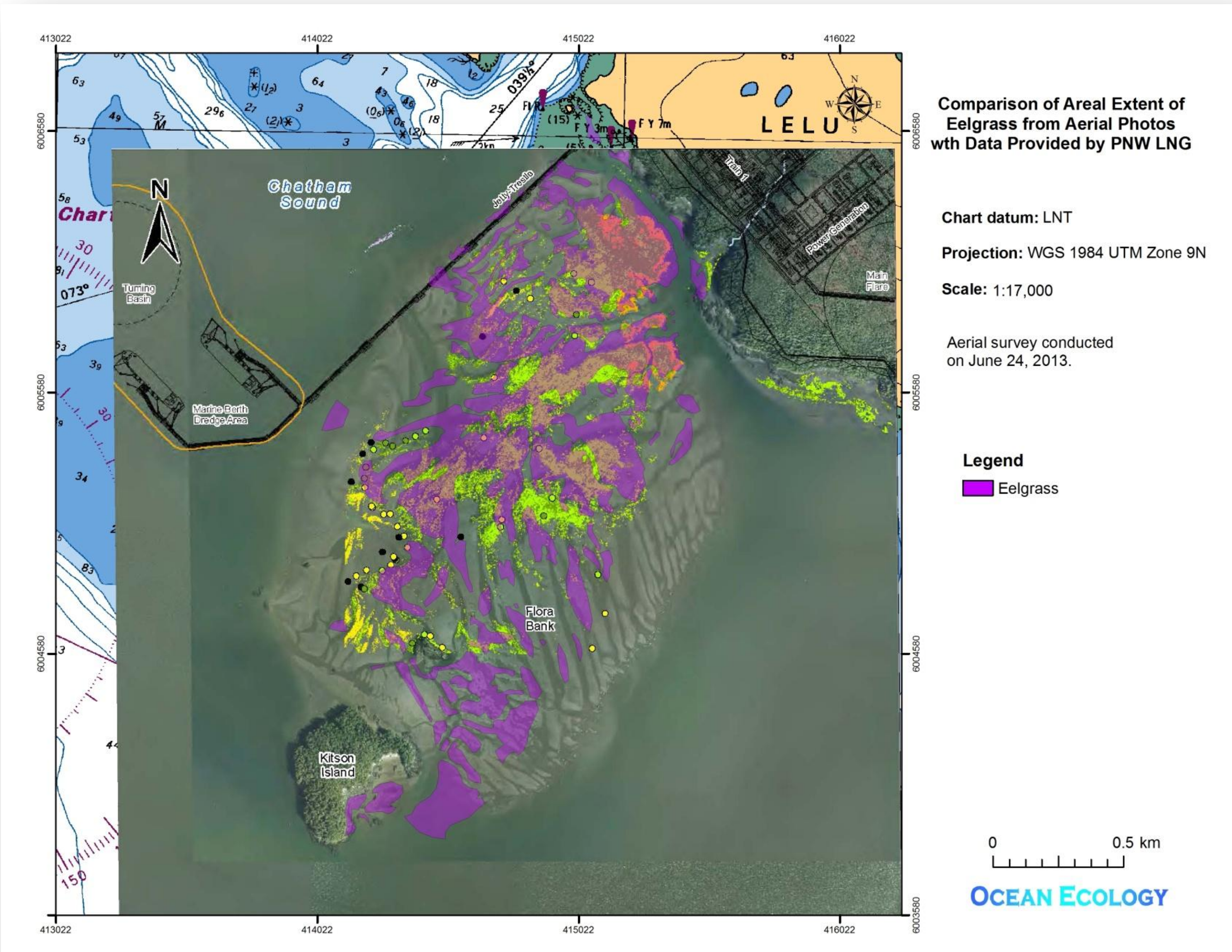

Figure 5. Comparison of the areal extent of eelgrass on Flora Bank based on the 2013 aerial survey with the proponents' data.

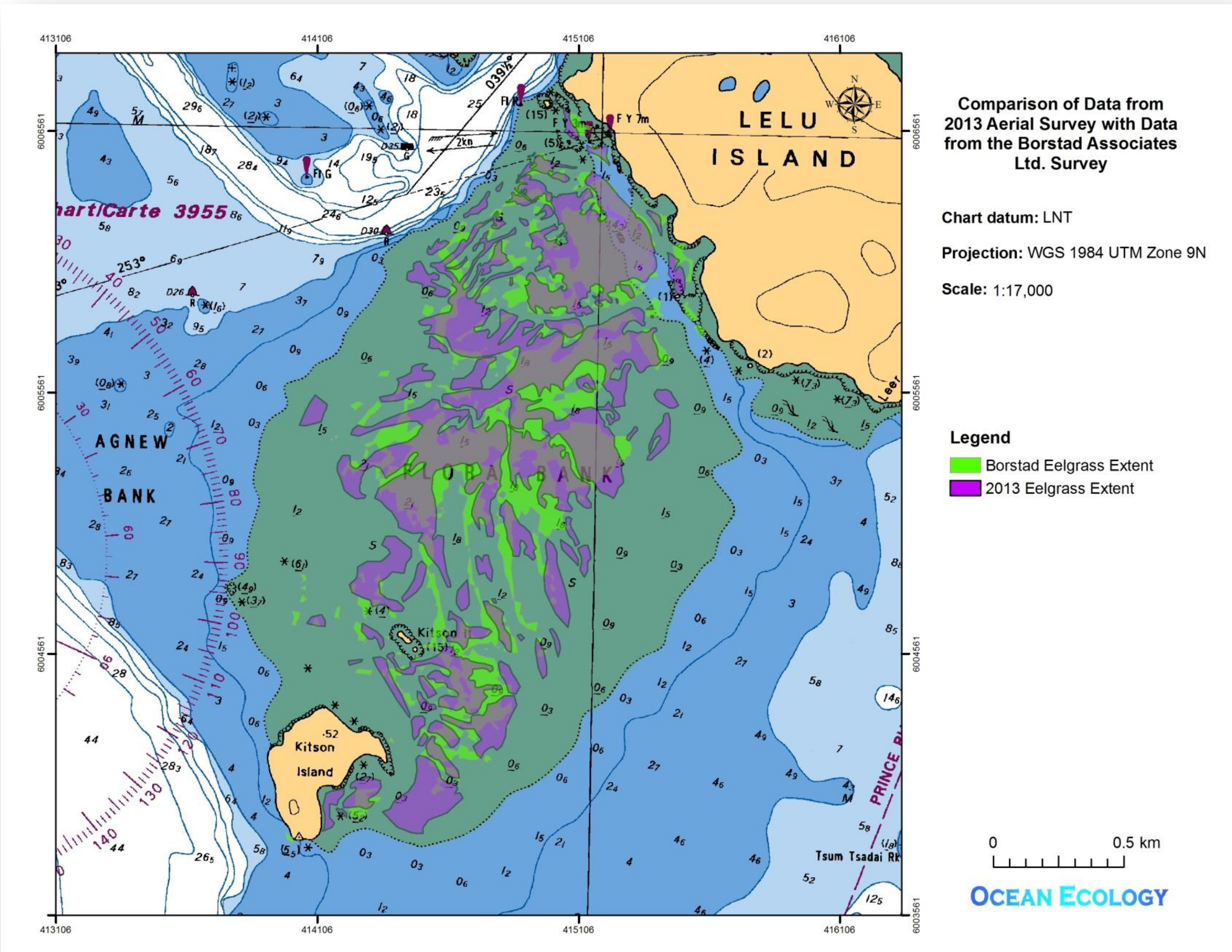

Figure 6. Comparison of areal extents of eelgrass on Flora Bank based on the 2013 aerial survey and the Borstad Associates Ltd. survey.

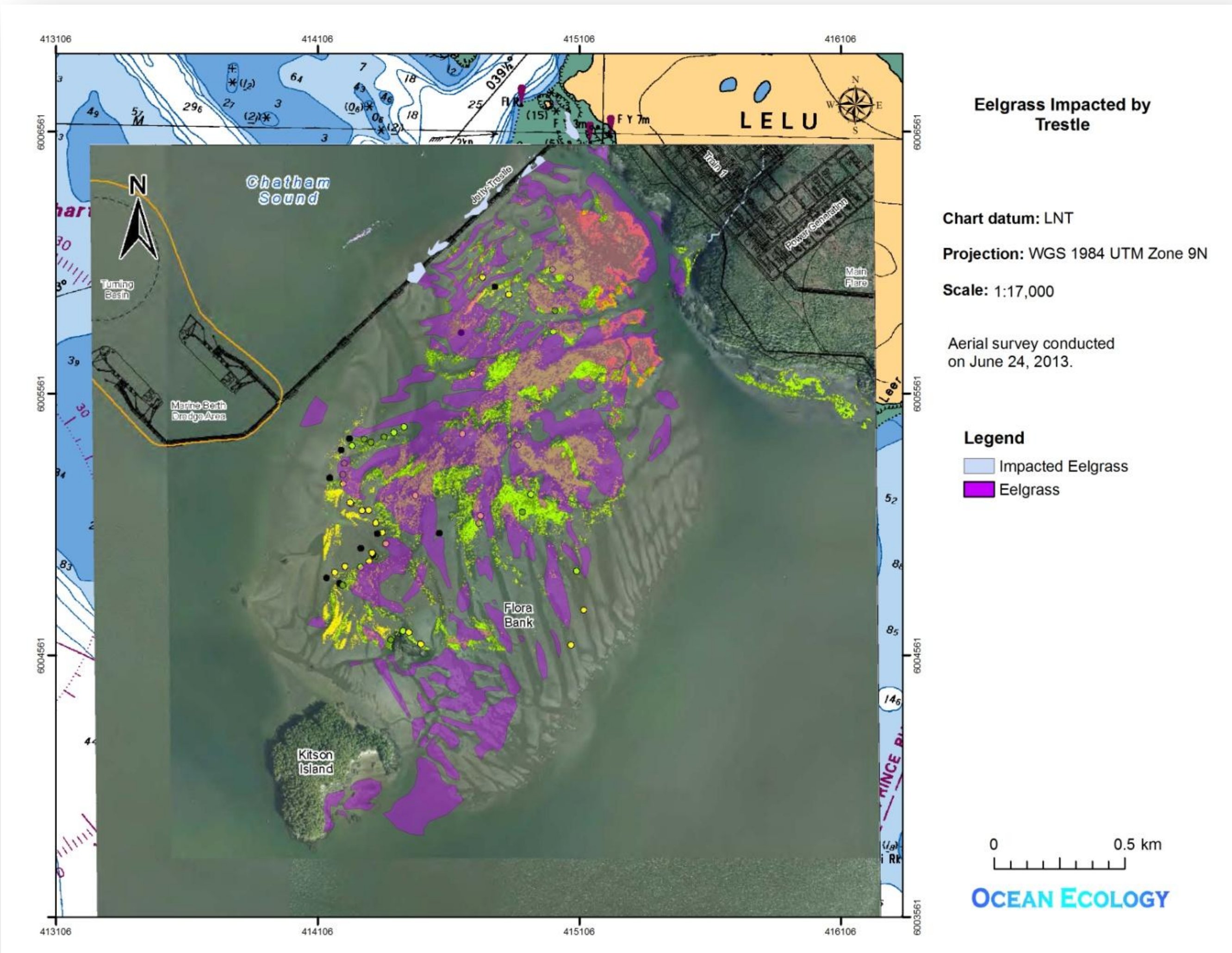

Figure 7. Eelgrass impacted by the proposed trestle based on the 2013 aerial survey.

2. Juvenile Salmonid Habitat

The proponents appear to be uncertain with respect to the degree of importance to place on the value of Flora Bank as juvenile salmonid habitat. On the one hand, the proponent makes statements such as "*The eelgrass beds on Flora Bank are ecologically valuable to the region and provide rearing habitat for out-migrating salmon, predominantly from the Skeena River*" (EIS, Section 13 - Marine Resources, pg. 13-18) and "*Flora Bank supports an eelgrass bed that is recognized as a biologically rich area, and an important resource for Skeena River salmon*" (EIS, Section 13 - Marine Resources, pg. 13-40). However, on the other hand, they quote data from one of my papers on eelgrass in Chatham Sound (Faggetter 2013), which seems (when taken out of context) to imply that damage to Flora Bank would be unimportant as there are other healthier beds which can be used by out-migrating Skeena River salmonids:

> *Flora Bank is expected to remain intact and continue to provide refuge for out-migrating salmon and eulachon from the Skeena River. In addition, several other eelgrass beds have been documented throughout the LAA* [Faggetter 2013]*, which likely also provide refuge for juvenile salmon and other CRA species. Some of these beds are larger and have higher eelgrass abundance than Flora Bank (e.g., Porcher Island near Useless Point and Tsimpsean Peninsula near Swamp Island). Several are also healthier than Flora Bank: of 29 eelgrass beds surveyed by Faggetter (2013), those at Flora Bank and Marrack Island were tied for the lowest health index of 2 (on a scale of 1 being the lowest and 10 being the highest). Two eelgrass beds near Porcher Island were ranked the highest (index of 8.5 and 9). Most of the eelgrass beds were ranked as having medium to high health, with 7 of 29 beds assigned an index lower than 5.* (EIS, Section 13 - Marine Resources, pg. 13-40)

Clearly, the question needs to be asked "Just how important is Flora Bank as juvenile salmonid habitat?". In answering this question, it is necessary to evaluate Flora Bank (or any eelgrass bed) on the basis of two factors: (1) quality of the habitat for juvenile salmonids; and (2) location of habitat relative to juvenile salmonid out-migration routes.

Recently, I carried out a study on the juvenile salmonid habitat in the Skeena River estuary region (Faggetter 2014). This research involved looking at 39 factors affecting habitat quality for juvenile salmonids, including factors such as shoreline morphology,currents, subtidal, intertidal, and riparian vegetation, anthropogenic shoreline modifications, predators, food resources, shelter, access to freshwater, dissolved oxygen in the water, sediment and water column pollutants, and water temperature. Shoreline segments were defined based on the morphological characteristics of the shore, and each shoreline segment was assigned a "habitat suitability index (HSI)" for each species of juvenile salmonid by applying species-specific habitat rules to the habitat factors. The HSI value was normalized to have a range between 1 and 10, with 1 being poor quality habitat ad 10 being good quality habitat (see Figure 8 as an example of the HSI values calculated for a single species).

Juvenile salmonids can be loosely grouped into two feeding categories. Epibenthic feeders are those species, such as chum, chinook, and pink, which spend the early part of their marine life in shallow water environments (e.g., eelgrass beds and sheltered subestuaries), feeding on organisms such as harpacticoid copepods and epiphytic crustaceans. Neritic feeders are those species, such as sockeye, coho, and steelhead, which spend the early part of their marine life in deep water environments (e.g., the estuarine plume), feeding on organisms such as neritic zooplankton and small fish. Flora Bank is a more important habitat for epibenthic juveniles (HSI of 8) than for neritic juveniles (HSI of 6). Flora Bank is still considered important for neritic juveniles, but they only spend a short period of time feeding in this habitat as they pass through it on their way to deeper water, whereas epibenthic juveniles spend weeks to months feeding in the shallow water areas until they are large enough to forage successfully in the neritic environment. Degraded epibenthic habitats force juveniles of these species into the neritic environment while they are still very small, leading to starvation and increased predation.

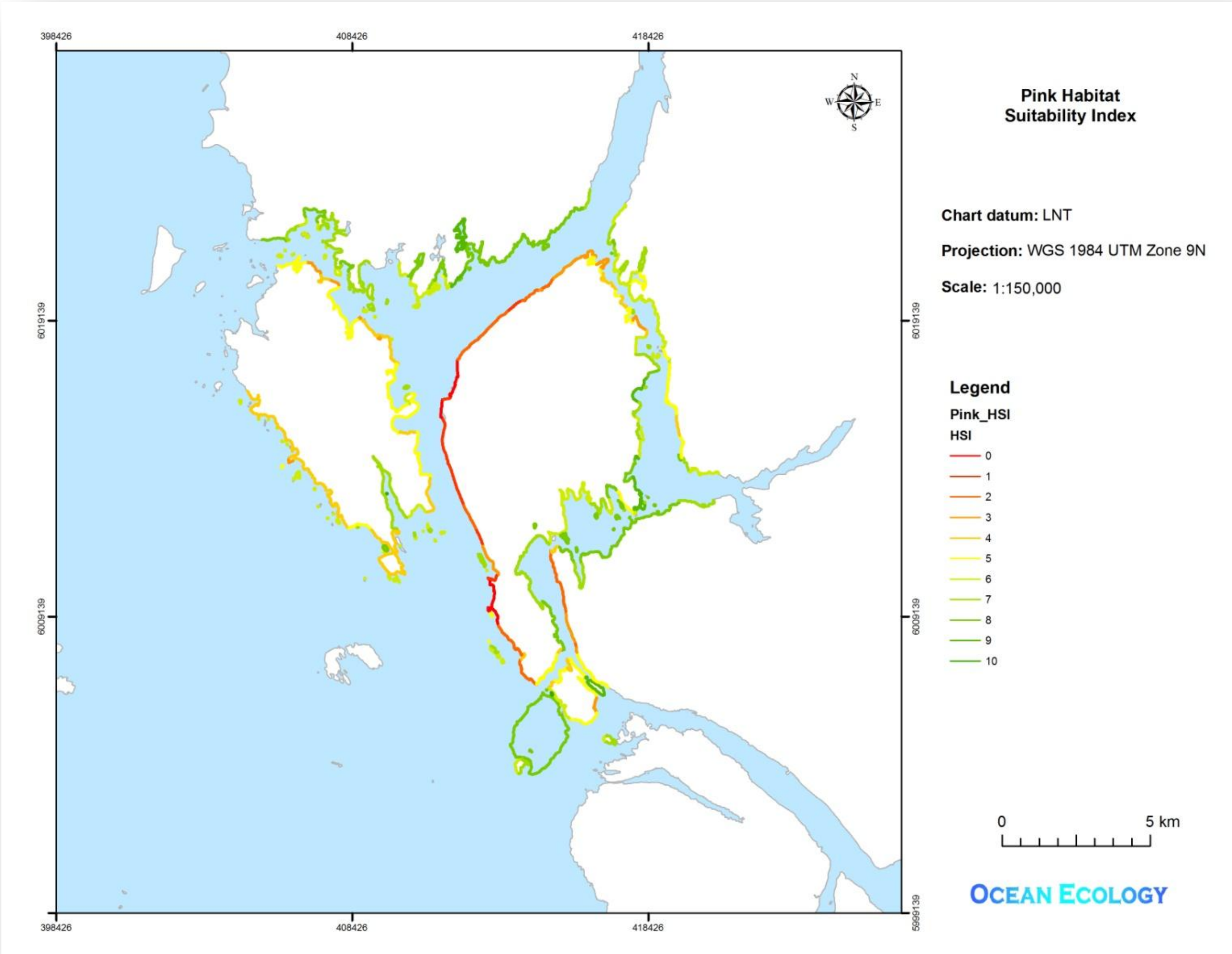

Figure 8. Habitat suitability index calculated for juvenile pink salmon (an epibenthic species).

To fully understand the importance of an HSI value of 8, it is necessary to consider the HSI values assigned to other nearby locations. Porpoise Channel has an HSI value of 4-5, the nearby Ridley Island shoreline has an HSI value of 2, and the Lelu Island shoreline has HSI values ranging from 3 to 6. Therefore, locally, in the area around Inverness Passage, Lelu Island, Porpoise Channel, and southern Ridley Island, Flora Bank has the highest HSI value, and is the best juvenile salmonid habitat in this region. In the entire study area for this research, a region which included all of Prince Rupert Harbour and the northern reaches of the Skeena River estuary, there were very few other shoreline segments which had HSI values equal to or exceeding that of Flora Bank, and these few segments were in the basins on the east side of Kaien Island and on the southern tip of the Tsimpsean Peninsula.

The HSI value that I calculated in this research was specific to the habitat requirements of juvenile salmonids. By comparison, my research on eelgrass beds throughout Chatham Sound (Faggetter 2013) was looking specifically at factors which contributed to the health of the eelgrass (turbidity, local freshwater, salinity, current velocity, wave exposure, sedimentation, cumulative sewage impact, average substrate particle size, and bottom slope). Although it may seem counter-intuitive, factors which promote a healthy eelgrass bed do not necessary ensure a high quality salmonid habitat. To illustrate this, it is useful to look at turbidity, a particularly important factor that contributes to eelgrass health. As turbidity increases, light penetration into the water column decreases, thus resulting in reduced photosynthesis and decreased eelgrass health. However, from the perspective of juvenile salmonid habitat, high levels of turbidity help to reduce predation on juvenile salmon, and thus increase the quality of the habitat. While this type of trend reversal between eelgrass health and quality of juvenile salmonid habitat is not true for all factors, it is significant enough that the relationship between eelgrass health and quality of juvenile salmonid habitat is not a simple linear one.

In addition to habitat quality, habitat location is vitally important to out-migrating juvenile salmonids, particularly those species which are epibenthic feeders. Species which require epibenthic food cannot travel far before they must find the right type of habitat for foraging. If they must travel any significant distance in open water, they will either starve or become food for predators. Thus, epibenthic juveniles out-migrating from the Skeena River would be unable to cross Chatham Sound to reach healthy eelgrass beds on Porcher Island. Therefore, it is erroneous for the proponents to believe that the various healthy eelgrass beds scattered throughout Chatham Sound will provide the same ecosystem functions with respect to Skeena River juvenile salmon survival that Flora Bank does.

Over 99% of the juvenile salmon in the study area for my research come from the Skeena River out-migration. The remaining juvenile salmon (less than 1%) come from small natal creeks and rivers in the region (e.g., Hays, Oldfield, Silver, McNichol, and Diana Creeks, and Kloiya River). Each year, approximately 377 million juvenile salmon swim out of the mouth of the Skeena River. The composition of this outmigration is roughly 72% pink, 21% sockeye, 3% coho, 2% chinook, 1% chum, and 1% steelhead (Faggetter 2014). Juvenile Pacific salmon migrating along the British Columbian coast instinctively turn northward as they exit their natal rivers and begin their migration along the coast to the Gulf of Alaska. Some individuals make this northward turn a little earlier than others during their out-migration. Based on beach seine and trawl catches of juvenile salmon in Chatham Sound (Carr-Harris & Moore 2013; Gottesfeld *et al.* 2008), we can estimate that approximately 88% of the juvenile salmon out-migrating from the Skeena River turn north into Inverness Passage. The remaining 12% travel through Telegraph Passage before turning north. Those juveniles traveling through Inverness Passage will pass over Flora Bank or around the shores of Lelu and Ridley Islands. Juveniles of species which forage in epibenthic habitats will remain in these areas until they are large enough to feed in the neritic environment. Thus, not only is Flora Bank a high quality habitat for juvenile salmon, it is in the direct path of approximately 331 million juvenile salmon, of which about 279 million are epibenthic feeders.

Other areas of high quality salmonid habitat in the study area, such as those shoreline segments in the basins on the east side of Kaien Island and on the southern tip of the Tsimpsean Peninsula, do provide habitat for salmon, but not those out-migrating from the Skeena River. Rather, these areas provide important rearing habitats for salmon out-migrating from the local natal streams. While these populations are small, they are important to the overall health and diversity of salmon in the region.

As a concluding remark, the proponents state "*Fish habitat offsetting measures will ensure no net loss in productivity, resulting in no adverse residual effects to fish habitat. Therefore, an assessment of cumulative effects is not required for fish habitat.*" (EIS, Section 13 - Marine Resources, pg. 13-77). From the above discussion, it should be clear that both location and habitat quality make Flora Bank an extremely important juvenile salmon rearing area. While it may be possible to duplicate similar high quality habitat elsewhere, that habitat would not play the same ecosystem function with respect to the large numbers of Skeena River juvenile salmon that Flora Bank does. Thus, fish habitat offsetting measures cannot ensure no net loss in productivity. Additionally, since any damage to Flora Bank will cause some loss in productivity, it is essential that the cumulative impacts of all the various projects occurring in the near vicinity of Flora Bank be studied carefully in order to determine the ultimate impact on the salmon in the region.

3. Disposal of Contaminated Sediments

The proposed facility is within the effluent plume of the old Skeena Cellulose pulp and paper mill (see Figure 9). Consequently, the proponents will need to be concerned with the possibility that the sediments in and around their proposed facility are contaminated, particularly with dioxins and furans. The proponents have provided sediment quality data for the MOF (materials off-loading facility). However, they have not provided data regarding the nature of the sediment in the marine terminal area. Why has this data not been provided? We can assume that the marine terminal region has sediment chemistry similar to the MOF and other projects in the near vicinity; however, it is important that the sediment chemistry of this region be examined in order to confirm this. If this is indeed the case, then the following statement given by the proponents regarding the MOF could also be considered true of the marine terminal area:

> *Dioxins and furans are a legacy of historical discharges at the former Skeena Cellulose pulp and paper mill on Watson Island, about 3 km from the MOF. They are of concern because they are taken up by biota and bioaccumulate in the food chain, leading to toxicological risks for vertebrates (fish, marine mammals, and humans). Dioxin and furan concentrations are reported as toxic equivalencies (TEQ) calculated using toxic equivalency factors (TEF) for fish based on the World Health Organization 1998 guidelines to allow comparison with the CCME ISQG (0.85 pg/g TEQ) and PEL (21.5 pg/g TEQ). In the MOF dredge area, TEQs ranged from 0.06 to 2.53 pg/g, and highest concentrations were measured in subtidal habitat, in the surface 0 to 0.4 m layers of sediment … TEQs for shallow sediment in subtidal habitat (from 0 m to 0.4 m or 0.5 m depth) were higher than the ISQG in six of the seven samples collected from surface grabs and cores, with a range of 0.68 pg/g to 2.64 pg/g. Sediment characteristics within the MOF dredge area are typical of the Prince Rupert area and do not indicate localized contaminant accumulations (results were similar to those from other locations around Lelu Island and from the Fairview Phase II and Canpotex programs). The exceedances of ISQG for copper and arsenic reflect baseline conditions for the area; they are consistent across the area at all depths of sediment.* (EIS, Section 13 - Marine Resources, pg. 13-14, 13-15)

In summary, some samples have arsenic, copper, and dioxin and furan values which fall somewhere between the ISQG (interim sediment quality guideline - this is generally based on the threshold effects level) value and the PEL (probable effects level) value. The ISQG is considered to be the minimal effect level at which adverse effects rarely occur, whereas the PEL is the probable effect level at which adverse effects frequently occur. If the concentration of a contaminant is less than the ISQG, adverse effects generally don't occur, and this could be considered the "green" zone. If the concentration of a contaminant is greater than the PEL, adverse effects are likely to occur, and this could be considered the "red" zone. If the concentration of a contaminant is greater than the ISQG and less than the PEL, then it is in the possible effects range within which adverse effects occasionally occur. This is the "yellow" or "caution" zone. The interpretation of what is necessary when sediments contain contaminants in the "yellow" zone is where many difficulties arise. This is particularly problematic when the contaminant of concern is bioaccumulative, such as dioxins and furans. The CCME (Canadian Council of Ministers of the Environment) makes the statement "*The ISQGs and PELs recommended for dioxins and furans do not specifically account for the potential for adverse biological effects on higher trophic levels that may result from dietary exposure. Therefore, TRGs* [tissue residue guidelines] *for the protection of wildlife consumers of aquatic organisms should be used in conjunction with the ISQGs and PELs to evaluate the potential for adverse biological effects on other components of aquatic ecosystems.*" (CCME 2001).

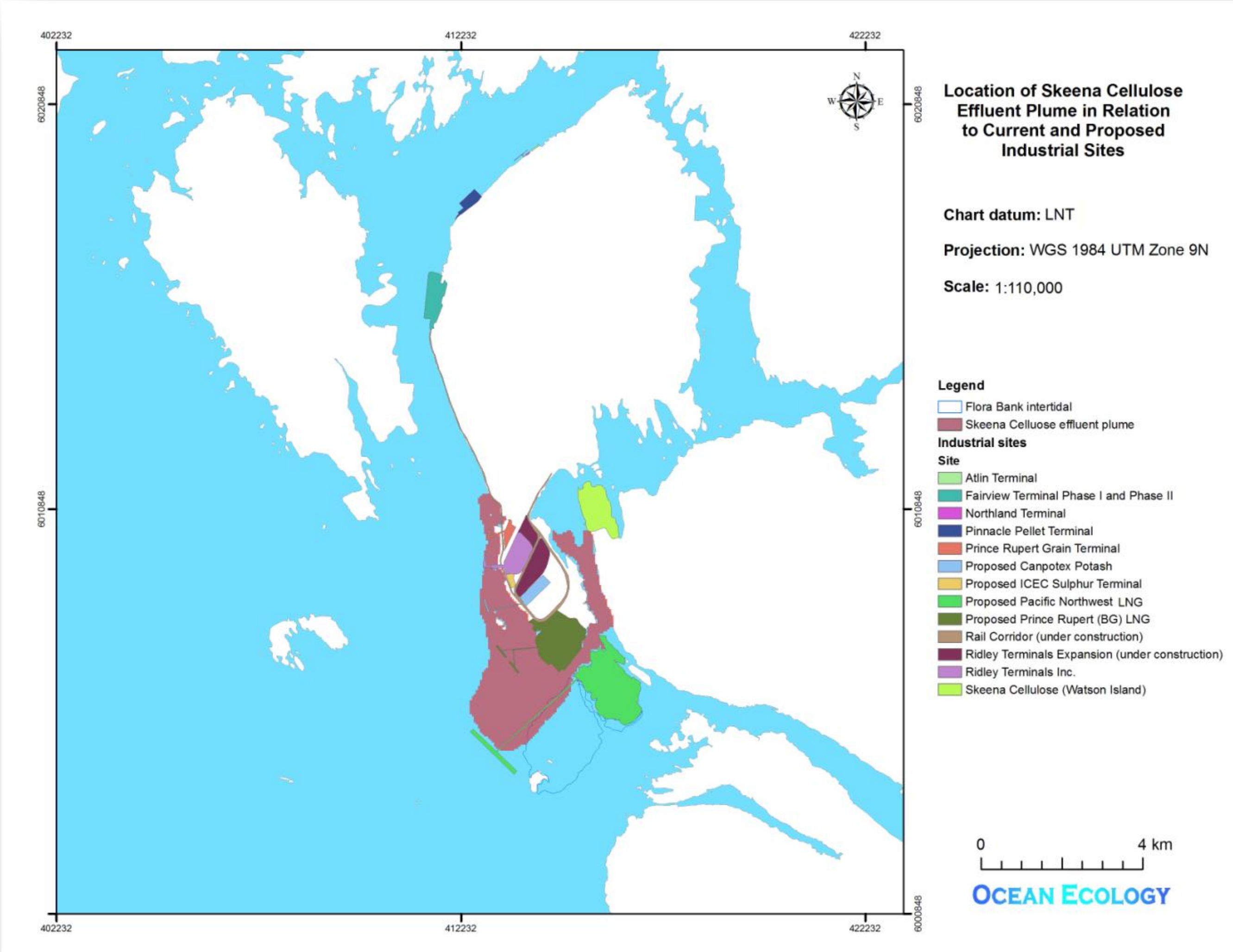

Figure 9. Location of the Skeena Cellulose effluent plume in relation to current and proposed industrial sites.

In the Puget Sound region of Washington State, recent changes have been made to the guidelines regulating the disposal of contaminated dredgeate in order to reduce the bioaccumulative risk to human and ecological receptors from dioxin (DMMP 2010). The guideline was set at 4 ng TEQ/kg (or 4 pg TEQ/g) for open-water dispersive sites and enclosed water non-dispersive sites (for non-dispersive sites, sediment with up to 10 ng TEQ/kg in a dredge unit can be disposed of as long as the volume weighted average concentrations is 4 ng TEQ/kg or less). A TEQ is a toxic equivalent relative to 2,3,7,8-TCDD, the most toxic dioxin cogener. A TEF is a toxic equivalency factor. The TEFs used to calculate the TEQ for this guideline are the WHO 2005 values for mammals and humans (Van den Berg *et al*. 2006). Open water disposal sites are described as being either dispersive or nondispersive. In nondispersive sites, the dredged material remains within the disposal site boundaries. In dispersive sites, the dredged material is expected to leave the disposal site due to environmental forces, such as ocean currents. The proponents refer to this Washington State guideline as follows:

> *The TEQs calculated using WHO 2005 TEFs for mammals and humans were compared to the Washington State disposal guideline of 4 pg/g. Fewer exceedances of the 4.0 pg/g guideline were identified: 3 samples, compared to 12 for the CCME ISQG, with a maximum of 4.62 pg/g. This included two samples from the dredge area (PCL01-01 and PCS03-01 from surface layers) and one from outside the PDA (SD1, a reference sample).* (EIS, Appendix L - Technical Data Report - Marine Sediment and Water Quality, pg. 42)

While the proponents point out that there were fewer exceedances of the Washington State guideline than the Canadian CCME (not surprising, since the Washington State guideline is set at a higher level), it should be highlighted that there were exceedances of both guidelines. When exceedances occur, Washington State describes a clear course of action, one which is worthy of consideration with respect to the current proposal:

> *Case-by-case decisions to allow disposal of material not meeting the screening levels may be made by the DMMP* [Dredged Material Management Program] *Agencies based on the overall goal of meeting the Non-dispersive Disposal Site Management Objective* [4 pg TEQ/g for surface sediments within the boundary of a disposal site]*. Case-by-case considerations will include the following: (a) material placement sequencing; (b) consideration of the possible cumulative effects of other bioaccumulative compounds within the project sediments; and (c) the frequency of disposal site use.* (DMMP 2010)

Furthermore, the DMMP states if a "*dredging unit is found unacceptable for non-dispersive disposal under case-by-case decision-making, the dredging proponent will have the option of pursuing bioaccumulation testing to determine whether or not individual DMMUs* [Dredged Material Management Units] *could qualify for open-water disposal. This option will be based on a modified version of the Tier III testing procedures included in the existing DMMP Users Manual.*" (DMMP 2010).

Based on the above discussion, the following salient points can be made:

1) Dioxins and furans are bioaccumulative, and there may be a bioaccumulative risk to both human and ecological receptors.
2) The CCME recommends the use of TRGs (tissue residue guidelines) when there is potential for adverse biological effects on higher trophic levels.
3) Safe disposal of contaminated sediments must take into account bioaccumulative risks, dispersal (e.g., by currents, waves, etc.), and frequency of disposal (e.g., cumulative impacts based on repeated exposures to contaminated sediments).

An ecological risk assessment (ERA) is performed to predict the probability of adverse effects occurring in an ecosystem or any part of an ecosystem as a result of a perturbation. When carrying out an ERA on an ecological component (e.g., a species of fish, mammal, or invertebrate), the CCME (1997) recommends examining the following in order to determine the degree of exposure from a stressor (e.g., dioxins and furans):

1) What are the significant routes of exposure?
2) To what amounts of each contaminant are organisms actually or potentially exposed?
3) How long is each exposure?
4) How often does or will exposure take place?
5) What seasonal and climatic variations in conditions are likely to affect exposure?
6) What are the site-specific geophysical, physical, and chemical conditions affecting exposure?

The extent to which the proponents have carried out these studies in not clear in the EIS report. In some circumstances (see comments below and in section 5), the proponents do not appear to have considered repeated exposures, potential dispersal of contaminated sediments, and resuspension of contaminated sediments.

The proponents considered nine sites for disposal at sea of marine sediments (EIS, Section 2 - Project Description, pg. 2-42). Of these nine sites, four were considered feasible - Sites 3 (southwest Kinahan Islands), 5 (southwest corner of PRPA boundaries), 8 (Stephens Island), and 9 (Brown Passage) (EIS, Section 2 - Project Description, pg. 2-43). Ultimately, site 9 was chosen as the most feasible site as "*it has the highest capacity for disposal, is the most well studied area, has the fewest nearby commercial fishing areas, and has been previously used for disposal*". However, the proponents comment that it is also the farthest from Lelu Island. In response to this, they note that "*Site 3 also has sufficient capacity and is the closest of the feasible alternatives, but local knowledge holders have indicated that this area is of particular importance for commercial prawn and shrimp harvesting*". (EIS, Section 2 - Project Description, pg. 2-46). It is unclear at this point whether Site 9 is the definitive final choice, or whether Site 3 remains a possible alternative that could still be used.

Based on the preliminary decision to use Brown Passage (Site 9) as the preferred disposal option, the proponents modeled the potential distribution of the dredgeate at this site. The outcome of this model was as follows:

> *The total bottom accumulation 20 days following the completion of all dredging disposals shows that all suspended disposal sediments will have settled out on the seabed. Most of the dredging materials will be deposited in the deeper water within the southeast area of the designated disposal site where water depths are greater than 150 m and where the near-bottom ocean currents are relatively weak, usually less than 0.2 – 0.3 m/s. About 71% of the total volume of dredge material is predicted to be deposited within the designated disposal area (1 nautical mile in diameter), to a thickness ranging from 29 mm to 2.1 m. The deposition spread within an area outside the disposal site occurs from UTM Easting 383000 m to 391500 m and UTM Northing 6014500 m to 6021000 m (8.5 km × 6.5 km). In this area a thickness greater than 5 mm covers the area from UTM Easting 384000 m to 388200 m and UTM Northing 6017500 m to 6020200 m (4.2 km × 2.7 km). Most of the regions with total bottom accumulation greater than 1 mm will occur in water depths exceeding greater than 100 m.* (EIS, Appendix O - Dredging and Disposal Modeling for Dredging off Lelu Island, pg. 27)

This model clearly shows that the Brown Passage disposal site is dispersive in nature (e.g., the dredged material is expected to leave the disposal site). However, the accuracy of this model is questionable. The model was calibrated using ocean current data from a DFO current meter mooring located at the site (Jiang & Fissel 2012). While the maximum depth of the Brown Passage site is 200 m (EIS, Section 2 - Project Description, pg. 2-46), the depths from the current meter used for calibration were 15 m and 98 m (data from Sep. - Oct. 1991; Jiang & Fissel 2012) - roughly 100 m above the sea bed. McGreer *et al.* (1980) state the following in their paper "*Review of Oceanographic Data Relating to Ocean Dumping in the Prince Rupert Area with Comments on Present and Alternate Dumping Sites*":

> *To assess the dispersion or spreading of dumped material requires data on:*
>
> *iv) bottom current velocity and direction (at 100 cm above the sea bed),*
> *v) bottom pressure,*
> *vi) water depth, and*
> *vii) bottom sediment characteristics.*

They further emphasize the importance of measuring bottom current velocity by saying "*bottom data … collected 10 or even 20 feet above the seabed … are of little or no value for bedload movement calculations, which require data at a maximum of 1 m (100 cm) above the sea bed*" and "*The single most important data set for the assessment of dispersion rates is bottom current velocities (at 100 cm above the sea bed)*" (McGreer *et al.* 1980). Thus, it is unlikely that the model given by the proponents is accurately reflecting the true dispersion of dumped material at the disposal site, and hence assumptions made about the ecological risks that contaminated sediments might pose to the environment based on this model are also unlikely to be accurate.

The issues associated with attempting to model sediment dispersal in the absence of bottom current velocity data can be seen more clearly by examining Site 3 (southwest Kinahan Islands), a possible alternative disposal site. As with Brown Passage, the potential distribution of dredgeate at the site was modeled (Jiang & Fissel 2011), with the following outcome:

> *At site 2* [Site 3 - southwestern Kinahan Islands]*, when all suspended sediments have settled out onto the seabed after completion of all project discharges, most disposal materials are deposited in the deeper water to the ESE and N of the disposal site where water depths exceed 50 m and where near-bottom ocean currents are relatively weak, usually less than 0.2 – 0.3 m/s. Total deposition within the disposal area accounts for 51.65% of the total dredging material, with a deposition thickness ranging from 200 mm to 1155 mm. The area with total deposition greater than 1 mm is located in areas of deeper water where water depths are greater than 50 m. The total deposition within this area accounts for 73.3% of the total terrestrial overburden material discharged to the ocean.*

Similar to Brown Passage, we see that the model indicates that this site is also dispersive in nature, and has weak bottom currents. The site has a maximum depth of 160 m (EIS, Section 2 - Project Description, pg. 2-46), and the model was calibrated at 16 m (data from May. - Sep. 1982; Jiang & Fissel 2011) - 144 m above the sea bed. Again, there is reason to suspect the accuracy of the model in predicting sediment dispersal; however, in this case, there is more information on which to base concerns. During field work at this site, I observed the following (Faggetter 2011b):

> *Significant currents were observed along the sea floor at the majority of the camera drops. Fine-grained sediments and plankton were often in continuous motion across the camera's field of view. Based on the movement of particles across the camera's field of view, it was estimated that at some drops the velocity of the bottom current was as high as 1.5 m/s (5.4 km/h or 2.9 knots).*

Thus, the current along the sea bed of Site 3 is considerably stronger (5 x) than the current expected by the model used to determine sediment dispersal. These deep water flows can be explained on the basis of estuarine currents:

> *Examination of the local topography around Site 2* [Site 3] *shows that there is a well-defined trough leading from outside the Rachael Islands to the mouth of Inverness Passage. This trough probably forms a conduit for deep water movement from offshore to replenish losses due to estuarine entrainment, and also acts as a funnel, thus increasing the velocity of bottom currents along the route. Site 2* [Site 3] *is located directly along this potential path of deep water flow, and this is most likely the explanation for the strong currents observed by the drop camera survey.* (Faggetter 2011b)

Dumped material at Site 3 would likely be carried in a southeast direction towards the mouth of the Skeena River. Again, any assumptions made about the ecological risks that contaminated sediments might pose to the environment based on this model are unlikely to be accurate. In fact, in this case, there is a significant potential that the contaminated sediments could be widely dispersed, and possibly carried into sensitive habitats near the mouth of the Skeena River.

Interestingly, McGreer *et al.* (1980), in their review on ocean dumping in the Prince Rupert area, which included both Brown Passage and Site 3 amongst 6 others, reported:

> *The site most highly recommended for disposal of contaminated material was Tuck Inlet. It was the most suitable site according to biological resource data and the second most suitable site in terms of physical oceanography criteria … The site most suitable for dumping of clean materials was Ogden Channel. It rated third overall for biological criteria and fourth for physical oceanography … Brown Passage was the second most suitable site for dumping clean material.*

Site 3 (referred to as Kinahan Island Basin in this report) was rated the least suitable as a disposal site based on biological resource data and the fifth least suitable out of the 8 sites for contaminated material disposal based on physical oceanography criteria.

A human health risk assessment (HHRA) is normally carried out to estimate the risk of potential adverse health effects on an individual, community or population that could arise from changes in environmental quality due to the proposed project alone and combined with the cumulative impact from other existing and planned projects, as well as inclusion of ambient or background conditions in the region (AWH 2011). HHRAs try to assess the following (Kindzierski *et al.* 2011):

1) *what the contaminants of concern for potential human health impact are –* ***chemicals***
2) *how and where they are released into the environment, and what pathways they are in (e.g., air, water, food, or soil) –* ***exposure pathways***
3) *who may be exposed to them –* ***people***

In addition to the assessment of potential health risks to members of the population in general, consideration must be given to individuals within a population who may be at greater risk. Critical subgroups are considered to be those whose lifestyle and behavioural characteristics may contribute to greater chemical exposures than the general public. This would include children or individuals consuming greater than average proportions of country foods and other natural foods (e.g., Aboriginal peoples and residents subsisting predominantly on locally grown produce, and traditional foods such as plants, wild game and fish) (AWH 2011).

Given (1) the bioaccumulative nature of dioxins and furans, (2) the significant number of sediment samples that have dioxin and furan toxicity values falling between the ISQG and PEL limits, (3) the likelihood of repeated exposures as a result of multiple proposed projects involving dredging of contaminated sediments in the region (e.g., Canpotex, BG LNG, PNW LNG, etc.), (4) the limited understanding of the region's oceanography, especially bottom currents and the potential for dispersal and resuspension of contaminated sediments, (5) the potential of improper disposal of contaminated sediments (see section 5) resulting in continuous resuspension of these sediments, and (6) the significant percentage of the local population who are either First Nations or practice subsistence living and who thus eat large amounts of country foods, it is essential that a human health risk assessment for the area be carried out. It is clear that the proponents recognize the potential for a human health risk, as they report:

> *Dietary exposures of various contaminants of concern include metals, extractable petroleum hydrocarbons, polycyclic aromatic hydrocarbons (PAH), polychlorinated dibenzo-p-dioxins and polychlorinated dibenzo-p-furans (PCDD/F). Health Canada has calculated tolerable daily intakes for assessing potential human health risks. These are used in country foods risk assessments.*
>
> *CCME and the US Environmental Protection Agency provide ecological toxicity reference values to assess chemical exposures to ecological receptors. Exposure pathways include ingestion and dermal exposures. Ingestion exposures include chemical uptake from food, water and soil associated with vegetation ingestion. Tissue body burdens are used to assess the chemical exposure from vegetation and prey items.* (EIS, Section 19 - Human and Ecological Health, pg. 19-3)

However, this is a very generic statement, covering many potential chemicals and exposure pathways. In order to do an HHRA, it is necessary to identify the specific critical subgroups which may be affected, and the specific pathways by which each of those groups is exposed. The proponents do make some attempt at doing this, but again in a very general way:

> *Consultation with Aboriginal groups and the public identified dredging activities as a potential concern to people consuming locally harvested seafood. Local people are concerned that marine sediments at Lelu Island may contain PCDD/Fs from historical industrial activities. The physical disturbance of marine sediments from dredging activities could result in a sediment plume that could carry the sediment-bound PCDD/F into the water column along with the suspended sediment particles. Marine organisms such as fish and benthic organisms could come into contact with these suspended particles in the water column or on surface sediments as the particles resettle. Local resource users were concerned this could adversely affect the quality of marine foods that people harvest for personal consumption or commercial resale … Sediment-dwelling marine organisms such as Dungeness crabs, prawn and various clam species could uptake and bioaccumulate historically deposited PCDD/Fs in fat tissues, subsequently passing the chemicals to ecological receptors up the food chain or to people who consume these tissues.* (EIS, Section 19 - Human and Ecological Health, pg. 19-3 - 19-4)

Typically, an HHRA would involve detailed surveys of local diets to get information on both the types of foods eaten as well as the quantities of each type. This would then be followed up by a food chain analysis to determine potential pathways of exposure. Instead, the proponents report the following:

> *A baseline survey of marine country foods was conducted due to concerns from First Nations and local residents about the potential for adverse chemical effects to marine biota (i.e., clams, crabs and prawns) and subsequent effects to humans consuming these tissues.* (EIS, Section 19 - Human and Ecological Health, pg. 19-15)

This baseline survey involved the following:

> *In September 2013, samples of crab (Metacapus magister), clam (Macoma sp., Mya arenaria) and prawn (Pandalus hypsinotus) were collected within 3 km of the MOF based on the anticipated sediment plume distribution and the southern end of Lelu Island where the proposed natural gas feed pipeline would enter the facility. Samples were analyzed for all congener classes of PCDD/F. These samples include 16 crab muscle, 16 composites mixtures of Macoma sp. and Mya arenaria, and 8 prawn samples.* (EIS, Section 19 - Human and Ecological Health, pg. 19-16)

The proponents do not identify which critical subgroups ingest each of these organisms, nor do they identify the exposure route for each of these organisms (it is assumed to be dermal exposure and/or ingestion, but this should be examined in more detail). Crabs and prawns are generally harvested for commercial resale, and probably only represent a small percentage of the diet of First Nations and local residents. Macoma and soft-shell (*Mya* sp.) clams are small, mud-dwelling clams than are not typically eaten by any local human consumers. However, several species commonly eaten by local residents (e.g., butter clams, cockles, salmon, and *Porphyra*) were not tested. The exposure routes of the sampled organisms are also likely to be different, since crabs and shrimp are detritus feeders, whereas bivalves are filter feeders. Additionally, it would have been useful to observe values from secondary consumers, such as salmon, to determine levels of bioaccumulation.

Based on their survey, the proponents determined that the average PCDD/Fs in the muscle tissues of the sampled organisms was 0.33 ng TEQ/kg wet weight (ww) for mammalian consumers (EIS, Section 19 - Human and Ecological Health, pg. 19-16). This value was compared to the tissue residue guideline of 0.71 ng TEQ/kg ww. While the average value for PCDD/Fs was below the tissue residue guideline, the values ranged quite significantly, from 0.03 to 1.03 ng TEQ/kg ww. In light of the limited number of samples analyzed, and the fact that many of the organisms sampled do not represent the most significant pathways of exposure to First Nations and local residents, there is reason for concern that the proponents' baseline survey does not adequately reflect the human health risk potential of their proposed project.

4. Marine Habitat Offsetting Plan - Inverness Passage Salmon Migration Corridor

Inverness Passage (see Figure 10) is a relatively narrow northwest-southeast oriented channel which provides a migration corridor for juvenile salmon out-migrating from the Skeena River and traveling northward along the coast. Before considering marine habitat offsetting plans that alter this channel, it is strongly advisable to consider the function of the channel with respect to juvenile salmon, and the role it currently plays in their out-migration.

Inverness Passage is subject to a 3 knot (154 cm/s) alternating tidal current, and a maximum tidal range of 24.3 ft (7.41 m). The sustained swimming speeds of juvenile salmonids generally do not exceed 76 cm/s, with many of the smaller juveniles seldom exceeding 20 cm/s (Bainbridge 1960, Bell 1986, Brett 1982, Brett *et al.* 1958, Glova & McInerney 1977, Houston 1959, Smith & Carpenter 1987, Weaver 1963). As a result, most juveniles will not enter Inverness Passage during a flood tide (current flowing to the southeast), as they will be unable to swim against the current. Rather, they will mostly likely hold up in the area around Boneyard Creek and wait for high slack tide, at which point, they will enter Inverness Passage. Juvenile salmon, particularly epibenthic species, will not usually feed in currents greater than 5 cm/s. Since Inverness Passage rarely has current speeds this low, it is not considered a good foraging habitat for juvenile salmon. Furthermore, except at full high tide, when the upper marsh grass beds are partially submerged, there is very little foraging habitat available for young salmon. Thus, what little foraging the juvenile salmon carry out in Inverness Passage will take place only at high slack in the submerged marsh grass (see Figure 11). Inverness Passage is approximately 5.6 nautical miles long. At an average speed of 1.5 knots, it will take about 3.73 hours or 224 minutes for a juvenile salmon to traverse the passage. Given the rapid transit time and lack of foraging opportunities, Inverness Passage acts largely as conduit for juvenile salmon, quickly delivering them to higher quality foraging habitat, such as Flora Bank or the region around Stapledon Island (see Figure 12).

The proponents are proposing marine habitat offsetting plans that would alter Inverness Passage as follows:

> *The proposed habitat features within this migration corridor could include a variety of different types shallow-water reefs, including linear 'groyne reefs' extending outward from the shoreline, circular 'atoll reefs' in shallow portions of the Passage, and semicircular 'containment reefs' partially encircling points of freshwater inflow from small streams along the shoreline. The aim of this offsetting would be to increase the survivorship of juvenile fish by providing a connected network of suitable refuge areas as well as to increase available invertebrate prey items by boosting primary productivity in the area.* (EIS, Appendix K - Conceptual Fish Habitat Offsetting Strategy, pg. 16)

Furthermore, while the proponents state,

> *Exact locations of inwater structures and enhancement features would be decided upon following consultation with local Aboriginal groups, DFO, Skeena Fisheries Commission and other interest groups. In addition, further intertidal and subtidal studies would determine the optimal habitat features and the most suitable locations.* (EIS, Appendix K - Conceptual Fish Habitat Offsetting Strategy, pg. 16)

they do provide a figure showing their conceptual design (EIS, Appendix K - Conceptual Fish Habitat Offsetting Strategy, Figure 6). This figure shows several structures located at the southeast end of Inverness Passage in the mid to upper intertidal zone on the mudflats on both sides of the passage.

Figure 10. Aerial view of Inverness Passage at a 0 m low tide. Photo: Ken Rabnett.

Figure 11. Marsh grass beds along Inverness Passage at a 0 m low tide. Photo: Ken Hall.

Figure 12. High quality juvenile salmonid habitat around Stapledon Island. Photo: Ken Rabnett.

It is highly questionable what value these structures would serve. Given that juvenile salmon are only likely to be present in the passage during the ebb tide, and that the location of the structures is in the middle to upper intertidal zone, it is unlikely that these structures would be accessible to the fish for more than 6 hours on each tidal cycle. Furthermore, they would go dry at low tide, thus stranding any fish that took refuge in them. While it is possible that the structures might retain enough oxygenated water to keep stranded fish alive until the next tidal cycle, this is a design factor that would need serious consideration. Even if they were designed adequately such that fish could take refuge in them over a tidal cycle, such small structures would provide extremely limited feeding opportunities (keeping in mind that 297 million epibenthic juvenile salmonids pass through this channel each year). Would it not be better to allow the juvenile fish to complete their 4 hour journey unhindered through the passage, at the end of which time they would have access to high quality foraging habitat? Would the creation of these "micro-refuges" in an otherwise fairly barren mudflat simply provide a convenient feeding station for predators such as gulls and mergansers? These are important ecological questions which should be considered before such structures are proposed.

Groins and other similar structures are generally installed for the purpose of trapping sediment and/or slowing the movement of sediment along a shore (for example, on sandy beaches). However, in spite of the high currents that are present, Inverness Passage does not appear to have any shortage of sediment (see Figure 10 and Figure 11). Clearly the sediment supplied by the out-flowing Skeena River, and deposited at slack water along the shores of Inverness Passage, is equal to or greater than the amount of sediment eroded by the maximum flood and ebb currents. Further trapping of sediment in this system is unlikely to contribute significantly to the functions provided by the system. The lack of significant vegetation (e.g., primary productivity, potentially eelgrass) on the mudflats is largely in response to the very high sediment loads in the water column which create high turbidity, resulting in low light levels and reduced opportunities for photosynthesis, and high sedimentation, resulting in plant burial. Additionally, sediments in high current regimes tend to form dynamic, mobile deposits, which are generally not suitable for rhizomatous plants, such as eelgrass.

Finally, and possibly most importantly, there is little to be gained in trying to change something that is already functioning well. There are no indications, either from past or present studies, that Inverness Passage is limiting in some manner to the survival of juvenile salmon. It acts as a rapid conduit from the mouth of the Skeena River to high quality habitat. It needs no further modifications to provide this service - in fact, anthropogenic alterations may result in a reduction of this function, and possibly a decrease in salmonid survival. It is not justifiable to alter perfectly functional habitat simply because (1) it allows the proponents to meet the amount of habitat offsetting required by their proposed project, or (2) it reduces the amount of material that will need to be disposed on land or at sea.

5. Marine Habitat Offsetting Plan - Flora Bank Eelgrass Enhancement

The proponent proposes the following enhancement to Flora Bank:

> *To increase the ecological value of Flora Bank as habitat for juvenile salmon and other species of CRA importance, one conceptual option would involve amending sediment depths adjacent to the existing Bank to increase the area of suitable eelgrass habitat. Specifically, this would involve the beneficial re-use of sediment dredged from the berthing area to expand Flora Bank westward by raising the substrate depth to approximately +1.5 m CD, which is the depth at which the majority of eelgrass on Flora Bank currently resides. The sediment would be moved through a pipeline using a suction dredge. A containment berm would be created along the margins of the fill area, using small diameter crushed rock or another suitable material, to retain sediment and ensure stability of the expanded habitat. This option could increase the area of suitable eelgrass habitat by up to approximately 1.1 million m^2, thereby substantially increasing the productivity of the habitat with widespread benefits to juvenile salmon and other marine organisms. Eelgrass would be expected to naturally colonize the new habitat, but eelgrass transplants could also be undertaken to expedite the process. In addition, this option would reduce the amount of dredge material to be disposed of at sea.* (EIS, Appendix K - Conceptual Fish Habitat Offsetting Strategy, pg. 17)

The shape and extent of Flora Bank has not changed significantly over a period of many years. This is largely because Flora Bank is in equilibrium with the presently existing erosional/depositional regime of tides, currents, and sediment supply for the region. The southwest side of Agnew Bank has a significant exposure (e.g., long fetch) to winds coming from the south and west. These winds form steep, breaking waves in the shallow waters of Agnew Bank and to the northwest of Kitson Island (personal observations). Flora Bank has not naturally extended westward because this exposure to wind and wave action on that edge of the bank has constantly resuspended and removed any sediment which accumulates in the shallow water. Other areas on Flora Bank are more sheltered from wind and wave exposure by Kitson, Smith, and Porcher Islands, and thus deposition of sediment takes place more readily in these areas. Using data from the Lucy Island Lighthouse, significant wave heights for different wind regimes have been calculated (Tera Planning Ltd. 1993). The largest waves come from the south, which has the largest wind speeds, and the southwest, which has the greatest fetch. Significant wave heights for these waves is less than or equal to 3.3 m. The depth to which wave erosion can take place is roughly 1.5 x wave height, or in this case, 4.95 m. This agrees amazingly well with the depth of Agnew Bank, with is approximately 5 m at its outer edge. As a result, attempting to establish an eelgrass bed in this location will be challenging, as there will be a natural tendency for any sediments placed in this area to be eroded. While the proponents intend to place a containment berm along the margins of the fill area, this will not protect the surface of the fill from any waves that make it over the edge of the berm, particularly at high tide. Furthermore, waves breaking against the berm will tend to form progressive wave bores across the surface of the fill at higher tides, causing erosion and resuspension of the fill.

The proponents note with respect to this habitat offsetting concept that it "*would involve the beneficial re-use of sediment dredged from the berthing area to expand Flora Bank westward*" (EIS, Appendix K - Conceptual Fish Habitat Offsetting Strategy, pg. 17). While the proponents have not provided information with respect to the nature of this sediment, it may be assumed that it has contaminant concentrations similar to those found in other sediments in the near vicinity (see section 3). Placement of sediments with low level contamination in regions of high wave and tidal energy, or ongoing terminal operation in the form of prop wash and berthing activities, is likely to result in continual resuspension of these sediments. Consequently, organisms living in, over, or near these areas would receive numerous low level chronic exposures to these contaminants, increasing the likelihood of bioaccumulation, and ultimately, potential human exposure via the food chain. Although the proponents can be commended for their desire to beneficially re-use their dredgeate, this is not a justification for disposal of contaminated sediments in an inappropriate location.

6. Marine Habitat Offsetting Plan - Islets Constructed of Perimeter Berms

The proponents propose the following habitat offsetting concept:

> *In addition to the eelgrass habitat creation, a conceptual eelgrass enhancement option is also proposed. This would involve the creation of a series of small islets along the south side of Flora Bank using large diameter rip rap. The islets would then be filled with dredge material and organic overburden (e.g., soil) from Lelu Island would be used as growth medium. The existing seed bank in the soil would generate a natural community of shrubs and trees similar to that found on Lelu Island; however, additional plantings could also be undertaken to supplement natural generation. The intent of the islets would be to deflect the suspended sediments flowing out of the Skeena River (through Inverness Passage) southward, increasing the water clarity and decreasing the TSS levels over Flora Bank. The effect of this would be to increase light penetration through the water column, allowing eelgrass to establish at greater depths on the Bank. This would also promote the growth of existing eelgrass, leading to increased density. The rock used in the construction of the islets would provide hard substrate (which is limiting in the area) for a diverse community of algae and invertebrates, as well as fish.* (EIS, Appendix K - Conceptual Fish Habitat Offsetting Strategy, pg. 17)

It should be strongly stressed at this point that any proposed structure which interferes with the natural movement of sediments in the marine environment must undergo detailed oceanographic modeling to determine if there will be adverse impacts from the changes in sediment supply. Fortunately, the proponents do appear to recognize this, when they state:

> *The enhancement options presented here are conceptual at this time and will require additional technical studies (e.g., sediment transport/oceanographic modelling) to determine feasibility and effectiveness. Specific attention will be paid to ensuring that the proposed features will not adversely affect the physical or ecological integrity of Flora Bank, and that any options eventually implemented will result in substantial benefits in terms of ecological value and productivity.* (EIS, Appendix K - Conceptual Fish Habitat Offsetting Strategy, pg. 18)

It is extremely important that technical studies required in an EIS actually get done once the EIS is approved. It is also very important that if such studies show that adverse affects are likely, the proposed concept will either be discarded or modified such that the adverse affects do not take place. While this may seem like an over-emphasis on a process that should be indisputable, it is worth the reminder that in 2011, the Office of the Auditor General of British Columbia found that "*The EAO's* [Environmental Assessment Office's] *oversight of certified projects is not sufficient to ensure that potential significant adverse effects are avoided or mitigated*" (Sydor *et al*. 2011).

Of particular concern with this habitat offsetting concept are the following:

1) Depending on the width of the openings between the proposed islets, the sediment supply from the Skeena River, and the current velocity at the location of the proposed islets, there is a possibility that the openings could fill up completely with sediment, thus forming a total barrier to the current flow moving in a northwest-southeast direction. This would likely result in further sedimentation on the southward (Skeena) side of the structure, possibly resulting in shallowing of the entrance into Inverness Passage, and erosion on the northward (Rupert) side of the structure, possibly resulting in loss of eelgrass habitat. Current and sediment modeling would be required

to determine the probability of this occurring, and whether or not the proposed islets could be designed to avoid this problem.

2) The partial deflection of the plume away from Flora Bank may produce adverse affects on the Flora Bank ecosystem. Although deflection of the plume might enhance "*light penetration through water column, facilitating increased eelgrass growth*" (EIS, Appendix K - Conceptual Fish Habitat Offsetting Strategy, Figure 8), it will also reduce both sediments and nutrients flowing onto Flora Bank. It would be hard to determine the net effect on eelgrass growth in response to the competing influences of increased light and decreased nutrients. Additionally, Flora Bank would still be subject to high tidal energy and wave action from the north, which could erode the bank faster than a reduced sediment supply could maintain.
3) The proposed concept may have a detrimental effect on juvenile salmon. While the proponents suggest that the islets will "*provide access to Flora Bank for juvenile salmon; juvenile salmon are not trained for deep water thereby mitigating mortality attributable to predation*" (EIS, Appendix K - Conceptual Fish Habitat Offsetting Strategy, Figure 8), it is known that high levels of turbidity may help reduce predation on juvenile salmon (Fresh 2006; Gregory and Levings 1998 ; Simenstad *et al*. 1982). Since the proposed purpose of this concept is to reduce turbidity on Flora Bank, it may also increase predation on juvenile salmon, thus reducing their survival in this habitat.
4) The location of the proposed islets is an active fishing area. Placement of this structure could potentially have adverse affects on current commercial fishing activities. This would need to be investigated further.

In summary, it is not justifiable to "create" habitat in an oceanographically complex environment where the adverse impacts of the structures may outweigh their proposed benefits simply because (1) it allows the proponents to meet the amount of habitat offsetting required by their proposed project, or (2) it reduces the amount of material that will need to be disposed on land or at sea (e.g., blast rock, dredge material [potentially contaminated, see section 3], and organic overburden [e.g., soil] from Lelu Island).

7. Ongoing Disturbance of Flora Bank from Terminal Operation

Ongoing disturbance of the Flora Bank habitat from terminal operations, such as prop wash and berthing, has the potential to have adverse effects on the Flora Bank ecosystem. For example, it is known that there are decreases or changes in the epibenthos density, diversity, and assemblage at large overwater structures which are probably caused by the interacting factors of direct disturbance or removal by vessel traffic, reduced or compromised benthic vegetation, physical habitat alterations, and biological habitat alterations (Hass et al. 2002). These epibenthic changes can negatively affect the feeding and survival of juvenile salmonids.

The proponents state the following with respect to ongoing marine terminal operations:

> *During operations, TSS* [total suspended solids] *increases are expected as a result of vessel maneuvering during berthing. Preliminary modelling results for LNG carrier maneuvering assisted by four tugs on arrival and departure at the marine berth area indicate that TSS increases after one LNG carrier departure or approach are predicted to exceed the 5 mg/L above background WQG* [water quality guideline] *for continuous activities, reaching levels of approximately 500 mg/L over the northern portion of Flora Bank at low water slack. After 26 days of LNG carrier departures and approaches, TSS levels are predicted to exceed the 5 mg/L WQG over a larger area at low water slack, with a maximum TSS level exceeding 1,000 mg/L over a small area of Flora Bank at the trestle abutment.* (EIS, Section 13 - Marine Resources, pg. 13-28)

They explain further:

> *Modelling results and predictions for TSS levels are compared to the CCME WQG for the protection of marine aquatic life and BC Approved WQG, which are the same. For continuous activities (24 hours to 30 days), the WQG is an increase in TSS of no more than 5 mg/L above background. For activities of 24 hours or less, the WQG is an increase of no more than 25 mg/L above background. The continuous activity WQG is*

more appropriate to ongoing dredging activities and the shorter term WQG is more appropriate to individual disposal events. Water quality guidelines represent levels at which chronic (non-lethal) effects to marine aquatic life may occur. (EIS, Section 13 - Marine Resources, pg. 13-23)

It seems, from this information, that the maximum TSS levels of 500 to 1000 mg/L above background far exceed the CCME WQG for either continuous activities or for activities of 24 hours or less. Furthermore, according to the proponents, approximately one LNG carrier will berth at the marine terminal every two days initially, increasing to one carrier per day (i.e., 350 per year) (EIS, Section 13 - Marine Resources, pg. 13-63), so TSS levels will not return to background levels after the terminal begins operating. The proponents explain the effect of these high TSS values in terms of daily sedimentation:

> *Vessel maneuvering from LNG carriers and tugs during berthing and departure is likely to result in deposition of sediment over areas outside the marine berth area, with the greatest thickness (>37.5 mm) of sediment deposition occurring directly within the berth area over the short-term (22 hours after vessel departure and approach). During low water slack, the northwestern edge of Flora Bank will experience sedimentation, with maximum deposition (>37.5 mm) occurring over a small area near the jetty-trestle abutment.* (EIS, Section 13 - Marine Resources, pg. 13-28)

Therefore, with a vessel arriving at least once each day, the northwestern edge of Flora Bank could receive as much as 3.75 cm of sediment daily, especially if the vessels arrive and depart at low water slack. At a burial depth as low as 25% of the average above-ground plant height (4 cm), Mills and Fonseca (2003) reported that the probability of mortality exceeded 50% in both silt and sand sediment types. The probability of mortality increased rapidly when burial was 50% of plant height (8 cm). Clearly, 8 cm of sediment could be reached within a few days of terminal operation at some locations within Flora Bank. Studies have shown that a sedimentation rate of approximately >0.5 cm per year correspond with the loss of submerged aquatic vegetation (Cooper and Brush 1993, Cooper *et al*. 2004). Even if eelgrass is not buried by sedimentation, excessive amounts of particulate material settling on leaves can lead to plant mortality. The mechanism for damage appears to be reduced photosynthesis due to shading of leaves by the deposition of particulate material (Tamaki *et al*. 2002). Some of the highest density eelgrass on Flora Bank is located along the northwest edge of the bank (see Figure 4). The proponents' eelgrass surveys significantly underestimated the extent of eelgrass along the northwest side of Flora Bank (see Figure 5). Damage at the level described above could cause significant impacts to the ecology of Flora Bank and the organisms dependent on Flora Bank, such as juvenile salmonids.

In addition to habitat burial, high sedimentation rates can also have a direct impact on juvenile salmon. The proponents make the following statement with respect to TSS impacts on fish:

> *The maximum predicted TSS levels are higher than the 5 mg/L and 25 mg/L WQGs. Exceedances of the 5 mg/L WQG (continuous activity) are modelled to occur over the northern portion of Flora Bank and at the marine berth area as a result of vessel berthing. The WQGs are conservative and incorporate safety factors to protect marine life. Additional considerations for evaluating the potential for adverse effects come from published literature. Adult fish and highly mobile invertebrates typically avoid areas with elevated TSS levels and, therefore, exposure durations are generally limited to minutes or hours. It is likely that some individuals will experience chronic effects; however, changes in population viability are not expected, due to the small area where exceedances will occur, relative to available habitat including the majority of Flora Bank and the other eelgrass beds in Chatham Sound. Effects of vessel maneuvering during berthing are expected to be moderate in magnitude, local in extent, occur continuously over the long-term, and be reversible following operations within an area considered to have high resilience to these TSS concentrations.* (EIS, Section 13 - Marine Resources, pg. 13-32)

In reading the above, recognize that the primary concern regarding Flora Bank is the role it plays as a nursery habitat for juvenile salmonids (see section 1), not as a habitat for adult fish. Juvenile salmon out-migrating from the Skeena River do not have access to other eelgrass beds in Chatham Sound (see section 1). Therefore, reference to these habitats cannot be used as a justification for damaging the habitat on which they are dependent. While high levels of turbidity are actually beneficial to juvenile salmonids by reducing predation (Fresh 2006; Gregory and Levings 1998 ; Simenstad *et al*. 1982), these studies are referring to values of turbidity in the range of 27–108 NTUs. Epibenthic species (e.g., chinook) tolerate higher levels of turbidity (from 35 to 150 NTUs) than neritic species (e.g., coho and steelhead) which experience reduced feeding at levels as low as 25 to 45 NTUs (Gregory and Northcote 1993, Madej *et al.* 2007). It is hard to make a direct comparison between TSS and turbidity - the relationship is a linear one, but varies from location to location based on the type of sediments present in the water. However, Birtwell *et al.* (2008) provide some general guidelines with respect to determining levels of risk due to suspended sediment. At NTU values of >37.5-150, which are equivalent to TSS values of 25 - 100 mg/L, the suspended sediment risk to fish and their habitat is low. AT NTU values >600, which are equivalent to TSS values of >400 mg/L, the suspended sediment risk to fish and their habitat is unacceptable. TSS values at the proposed facility could be >500 mg/L. Carlson *et al*. (2001) documented that most juvenile salmon passing inshore moved offshore when encountering a dredge plume. Thus, while a little turbidity might be a good thing for juvenile salmon, a lot of turbidity is not.

8. Effects of Sound from Terminal Construction and Operation on Organisms Other than Marine Mammals

Anthropogenic noise can affect marine organisms in a variety of ways, including (Stocker 2002):

1) Tissue damage in extreme cases (e.g., very loud sounds).
2) Interference with normal sound production and reception, resulting in impacts on feeding, breeding, community bonding, schooling synchronization, and other acoustically-mediated behavior.
3) False triggering of behavioral responses causing an animal to expend energy unnecessarily. Large expenditures of energy that do not produce any positive benefits for an organism can make that organism unfit and less likely to survive.
4) Producing stress. Responses to stress can weaken organisms or damage community interactions.

Although the proponents have described at some length the effects of sound from terminal construction and operation on marine mammals (EIS, Section 13 - Marine Resources and EIS, Appendix N - Modelling of Underwater Noise for Pacific NorthWest LNG Marine Construction and Shipping Scenarios), their discussion on the effects of sound on other organisms, particularly juvenile fish, is relatively limited. With respect to direct injury, the proponents state the following:

> *In fish with swim bladders (e.g., salmon, herring, rockfish), pressure waves created by concussive impacts (e.g., pile driving) can rupture the swim bladder and/or damage other internal organs and tissue. Vulnerability to and the potential implications of such injuries, depend on the type of swim bladder a species possesses. Beyond this effect, auditory effects of underwater noise on fish are poorly understood.* (EIS, Section 13 - Marine Resources, pg. 13-46)
>
> *Despite the lack of information on auditory effects (injury) on fish, interim guidance criteria have been developed and adopted by the Fisheries Hydroacoustic Working Group for exposure to noise generated by pile driving:* SPL_{peak} *of 206 dB re: 1 μPa; and* SEL_{cum} *of 187 dB re: 1* $\mu Pa^2 s$*. This assessment considers exceeding these criteria to constitute a high potential for injury or mortality to fish.* (EIS, Section 13 - Marine Resources, pg. 13-47)

The proponents go on to describe behavioural responses as follows:

> *Potential behavioural responses of fish to underwater noise include change in behavior, small temporary movements for the duration of the sound, large movements that displace fish from their normal locations, and large-scale changes in migration routes. Construction noise is expected to trigger behavioural changes in fish that are close to construction activities. Behavioural changes in fish from non-pulse noises have not been well-studied but are likely to be greater in hearing specialists (e.g., herring) than generalists (e.g., salmon). Fish hearing specialists rely on auditory signals for*

communication, foraging and schooling; they have greater hearing sensitivity and perceive sounds over wider bandwidths than generalists. Species of importance to CRA fisheries most likely to be affected by underwater noise from construction are migrating salmon and eulachon. Most herring spawning occurs further away from the PDA, north of Digby Island and north of Porcher Island. Juvenile herring may be found in the LAA following spawning, potentially using Flora Bank and other eelgrass beds in the region for rearing. One deceased herring was observed in the eelgrass beds that were delineated during foreshore surveys near the jettytrestle abutment. Rockfish, lingcod, and Pacific cod (Gadidae) could also be affected, but are generally found further offshore, away from the construction area. The most common reaction is expected to be a short-lived startle response by fish near the onset of pulse noises (e.g., in close proximity to a pile during impact driving); however, normal behaviour is likely to resume within seconds. Some species may also move away from particularly noisy areas, but such reactions are expected to be minimal beyond 500 m of sound sources. (EIS, Section 13 - Marine Resources, pg. 13-57 - 13-58)

Hearing thresholds do not exist for behavioural responses in fish caused by underwater noise, unlike for injury. Behavioural changes have been reported in some species of rockfish (Sebastes spp.) for pulse-like sounds at (received) levels as low as 160 dB re: 1 μPa; however, several species of cod (family Gadidae) have been recorded resuming previous behaviours within seconds of pulses exceeding 200 dB re: 1 μPa. Herring have shown startle responses at received levels of 122 dB to 138 dB re: 1 μPa and clear behavioural responses when underwater noise was 20 dB to 25 dB above ambient noise levels. Nevertheless, researchers warn against extrapolating results of anthropogenic sound across contexts or different species of fish. This means that widely-applicable (i.e., across diverse species groups) behavioural thresholds for fish are not available. Therefore, the assessment of behavioural effects on fish is qualitative in nature and is based on available literature. (EIS, Section 13 - Marine Resources, pg. 13-60)

Since Flora Bank is a highly productive nursery area for juvenile fish, and since both the construction and terminal operation activities are in very close proximity to Flora Bank, there is a legitimate concern regarding the impacts of sound on juvenile fish utilizing this nursery habitat. Impacts which would cause juvenile fish to leave the nursery habitat prematurely, thus resulting in lost feeding opportunities and potential starvation, or which caused juvenile fish to develop behavioral responses (e.g., sound acclimatization) which could make them more susceptible to predation would be especially concerning. Based on the known range of salmonid hearing, sounds generated during pile driving activities are likely heard by fish within a radius of 600 meters from the source (Feist 1991). Feist (1991) determined that sounds generated during pile driving activities influenced both fish behavior and distribution of schooling salmonids in the vicinity of the site. On non-pile driving days the number of schooling salmonids drastically increased as compared to pile driving days. A study by Vagle (2003) discovered that juvenile chinook salmon and chum salmon became disoriented after exposure to sounds ranging between 40 and 50 kPa, and that mortality occurred with sounds in the range of 150 kPa. Juvenile chinook salmon displayed both flight and avoidance responses to sounds in the 10 Hz range (Knudsen *et al.* 1997). Further research is needed to determine if sound generated by normal terminal operation will affect the foraging behavior of juvenile fish on Flora Bank. Unfortunately, the proposed mitigation measures, "*vessels will not exceed a speed of 16 knots within the LAA*" and "*LNG carrier vessel speed will be reduced to 6 knots when approaching the Triple Island Pilot Boarding Station*" (EIS, Section 13 - Marine Resources, pg. 13-71) will do little to reduce impacts on juvenile salmon from vessel noise during berthing which is the location at which disturbances to the nursery habitat will be greatest.

9. Effects of Overwater Structures on Juvenile Fish

Overwater structures have been documented to pose the following potential risks for increasing mortality of juvenile fish utilizing shallow estuarine and nearshore marine environments (Nightingale & Simenstad 2001; Toft *et al*. 2007):

1) "Behavioral barriers" that can deflect or delay migration (including juvenile salmonids avoidance of swimming beneath overwater structures – shading effect).
2) Prey resource production and availability (e.g., "carrying capacity") limitations.
3) Altered predator-prey relationships associated with high intensity night lighting changes to the night time ambient light regime.

When shoreline-oriented juvenile salmonids encounter an overwater structure or deep riprap, they either swim under the structure or move into deeper water. When juvenile salmon schools are forced into deeper water by overwater structures, they change their behavior. This may have implications for within-species competition, feeding behavior, and susceptibility to predation (Toft *et al*. 2007). Ambient light patterns changed by night time artificial lighting on dock structures can change fish species assemblages and pose increased risk of predation by subsequent changes in night time migration, activity, and location of predators (Nightingale & Simenstad 2001). Prinslow *et al*. (1979) observed chum congregating below security lights. Significantly greater light intensities (200-400 lux) appeared to attract and delay chum.

The proponents recognize the potential of overwater structures with respect to shading:

> *The approximately 15 m wide jetty-trestle will stand clear of the water with an elevation ranging from 21.3 m (at the shore) to 13.5 m (seaward tip) above CD. Shading effects from the jetty-trestle are expected to be minimal due to its height, width and northeast-southwest orientation … The effects of artificial marine structures on juvenile salmon depend on the design and orientation of the structure, and effects on underwater light. The jetty-trestle will be oriented to avoid all but a small patch of the Flora Bank eelgrass, which will limit the shading effect for juvenile salmon. In-water structures, such as piles, can also change sediment-deposition regimes; such shifts could drive modifications in the structure of surrounding marine habitats.* (EIS, Section 13 - Marine Resources, pg. 13-37)

However, they do not discuss, or suggest mitigation options for, issues relating to deflection or delaying of migration and altered predator-prey relationships associated with night time lighting. Also, significantly more eelgrass than the proponents have estimated from their surveys is likely to be shaded (see section 1), thus invalidating their argument that they have avoided all but a small patch of the Flora Bank eelgrass.

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