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MAXIMIZATION OF SHIP DRAFT IN THE ST. LAWRENCE SEAWAY

VOLUME 2: IN-DEPTH ANALYSIS OF SQUAT AND UKC

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by

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16. Abstract

This volume presents an in-depth analysis of the squat behaviour and under-keel clearance (UKC) data for the St. Lawrence Seaway presented in Volume 1. The performance of the Tuck, Barrass 2 and Simard squat equations, and the effect of vessel speed and channel blockage are statistically quantified.

In addition to classical squat, water surges contribute a significant dynamic reduction to vessel UKC. To account for both classical squat and water level dynamics, "dynamic squat envelopes" are quantified for each vessel type and channel section. Although vessel sinkage is much less in Lake St. Louis than in the South Shore Canal, results show that there is little basis for distinguishing between vessel types.

The observed UKC of vessels for 31 transits is also examined in depth. Vessels are travelling very close to the channel bottom, but because the bathymetric data has not yet been fully "cleaned", it is as yet impossible to know for sure how close.

After careful review, it was determined that the negative UKC values reported in Volume 1 are probably all fictitious. Recommendations are made for improving the water level network and bathymetric survey and information system.

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16. Résumé

Ce volume propose une analyse détaillée des données relatives à l'enfoncement (ou *squat*) et à la profondeur d'eau sous quille pour la navigation dans la Voie maritime du Saint-Laurent, présentées dans le volume 1. Il présente également les résultats d'une quantification, par des méthodes statistiques, de l'efficacité des équations d'enfoncement Tuck, Barrass 2 et Simard, et des effets de la vitesse du navire et de l'obstruction du chenal.

Outre l'enfoncement classique, d'importantes fluctuations subites du niveau de l'eau entraînent une réduction dynamique de la profondeur d'eau sous quille du navire. Pour tenir compte à la fois de l'enfoncement classique et de la dynamique du niveau de l'eau, des «enveloppes d'enfoncement dynamique» sont calculées pour chaque type de navire et chaque section du chenal. Malgré un enfoncement relativement moindre dans le lac Saint-Louis que dans le canal de la Rive-Sud, les résultats ne permettent pas d'établir de critère net pour différencier les types de navires.

L'analyse porte également sur la profondeur d'eau sous quille observée pour 31 transits. Les navires s'approchent très près du fond, mais comme les données bathymétriques n'ont pas encore été complètement «épurées», il n'est pas encore possible de savoir précisément à quel point ils s'en approchent.

Après un examen minutieux, il a été déterminé que les valeurs négatives de profondeur d'eau sous quille dont il est fait état dans le volume 1 sont probablement toutes fictives. Des recommandations sont formulées visant l'amélioration du réseau d'enregistreurs de niveaux d'eau et les levés bathymétriques, et le système d'information connexe.

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We also acknowledge the monumental task of data collection, reduction and analysis carried out by Fleet Technology Limited, Waterway Simulation Technology Inc. and Géolocation Inc. We thank them for their full support and collaboration.

EXECUTIVE SUMMARY

To optimize vessel draft and ensure secure marine navigation, the overall study objective is to determine the magnitude of squat and under-keel clearance (UKC) of commercial vessels transiting the shallow waterways of the St. Lawrence Seaway (South Shore Canal, Lake St. Louis, Lake St. Francis and Wiley-Dondero Canal). The primary study was conducted by Fleet Technology Limited, Waterway Simulation Technology Inc., and Géolocation Inc. (F-W-G), which performed all the principal work and whose report is contained in Volume 1.

Volume 2 reports the findings of the Université Laval complementary study. The work was mandated and managed by the Transportation Development Centre (TDC), on behalf of the St. Lawrence Seaway Management Corporation (SLSMC) and its partners. TDC also contributed significantly at the technical level. The work was also sponsored by GEOIDE (centres of excellence in geomatics). Volume 2 is divided into four sections.

Section 1 (classical squat equations) studies the behaviour of ship squat. Specific emphasis is placed on the statistical quality of the Barrass 2, Tuck and Simard equations. There is little to distinguish between their respective accuracy.

Section 2 (dynamic squat equations) addresses data precision and reliability, and recommends the use of two simple equations to evaluate total ship sinkage due to squat and other dynamic effects. Regarding precision, the repeatability of measured squat values between two sailings of the same ship is assessed; the consistency of measured squat values of all ships within each type is evaluated; and it is determined whether each ship type has its own squat behaviour or whether there are trends between ship types. The conclusion is that all ship transits have *a qualitatively similar but statistically different squat behaviour,* regardless of whether the transit is the same ship on a repeat voyage, a ship of the same type or a ship of a different type (with the exception of Traditional Lakers, which seem to squat a little less than other ships).

During this analysis a second significant finding emerged: in addition to the mean value of ship squat (represented by a given squat equation), there are other important phenomena (such as water level fluctuations) that decrease the available UKC. Therefore, an alternative way of looking at the data was developed based on determining an equation that describes the maximum envelope of the measured squat values as a function of ship speed through water. This envelope is called the "dynamic squat equation". As a result, the dynamic squat equation takes into account not only the squat itself, but also the dynamic effects that are difficult to separate from the squat. Using this approach, it may be unnecessary to make a distinction between ship types. Therefore, the equation that encompasses all ship types for the South Shore Canal is:

$$\text{Canal Dynamic squat} = 0.0001763\ V^4 + 0.000407\ V^3 - 0.0065785\ V^2 + 0.0821755\ V$$

And the envelope for all ships passing through Lake St. Louis is:

$$\text{Lake Dynamic squat} = -0.0000229\ V^4 + 0.0017472\ V^3 - 0.016011\ V^2 + 0.0768478\ V$$

where "Dynamic squat" is the maximum total sinkage envelope value (expressed in metres) and V is speed through water (expressed in knots). The equations are only valid for V not exceeding 8 kn in the South Shore Canal and V not exceeding 12 kn in Lake St. Louis. For example, in the South Shore Canal a ship going 6 kn normally "squats" about 30 cm, but according to the envelope equation, it may occasionally squat a total dynamic value of 58 cm. At 8 kn, a ship may occasionally dynamically squat 116 cm. In Lake St. Louis, the same ship would only squat a maximum dynamic value of 39 cm at 8 kn but may reach 116 cm at 12 kn.

Section 3 is an investigation into the anomalous UKC values reported in Volume 1. The first objective is to identify all the critical sections of the Seaway where negative UKC values were identified by F-W-G. They are located either in the South Shore Canal or at the entrance of Beauharnois lock (none were found in Lake St. Louis per se). The second objective is to verify whether critical computed UKC values have a real physical significance. This is done by analysing whether critical UKC values coincide with a physical reality (shoal areas, excessive vessel speed, ship-meeting situations, water level fluctuations, etc.) or whether they can be attributed to errors (GPS, keel elevation, channel bottom elevation, water level, computational methods, etc.). The conclusion is that, although vessels were often very close to the Seaway bottom, the computed negative UKC values are probably all fictitious. They are a result principally of contaminated bathymetric data, although it seems that some stem from a “bug” that appears from time to time in F-W-G’s UKC calculation algorithm. Vessels were close to the bottom because of excessive speeds and significant water level fluctuations. Some bathymetric data are contaminated because they originate from files that as yet had not been adequately processed to remove spikes from the surveys’ raw data.

Section 4 provides recommendations to optimize bathymetric data gathering and reduction. The SLSMC survey team currently performs these surveys. Based on a site visit, recommendations are given regarding technical improvements that could be added to the team’s operations. It is recommended that a specific project be set up to provide systematically dependable, accurate and effective bathymetric surveys and water level information.

SOMMAIRE

La présente étude vise à déterminer les valeurs d'enfoncement et de profondeur d'eau sous quille des navires commerciaux qui transitent dans les eaux peu profondes de la voie maritime du Saint-Laurent (canal de la Rive-Sud, lac Saint-Louis, lac Saint-François et canal Wiley-Dondero), l'objectif ultime étant d'optimiser le tirant d'eau des navires et de garantir la sûreté de la navigation. L'étude principale a été menée par Fleet Technology Limited, Waterway Simulation Technology Inc. et Géolocation Inc. (F-W-G). Leur rapport est contenu dans le volume 1.

Le volume 2 présente les résultats de l'étude complémentaire réalisée par l'Université Laval, étude commandée par le Centre de développement des transports (CDT) au nom de la Corporation de gestion de la Voie maritime du Saint-Laurent (CGVMSL) et de ses partenaires. En plus d'assurer la gestion des travaux, le CDT y a largement contribué sur le plan technique. Enfin, le réseau de centres d'excellence en géomatique GEOIDE a participé au financement de l'étude. Le volume 2 est divisé en quatre parties.

La partie 1 (équations d'enfoncement classique) analyse le comportement d'enfoncement du navire. Elle se penche plus particulièrement sur la qualité statistique des équations Barrass 2, Tuck et Simard, lesquelles sont jugées d'une précision à peu près équivalente.

La partie 2 (équations d'enfoncement dynamique) porte sur la précision et la fiabilité des données, et recommande le recours à deux équations simples pour évaluer l'enfoncement total du navire dû au squat et à d'autres effets dynamiques. En ce qui a trait à la précision, les paramètres suivant sont analysés : la répétabilité des valeurs d'enfoncement mesurées pendant deux transits du même navire; la cohérence entre les valeurs d'enfoncement mesurées chez tous les navires d'un même type; l'existence de particularités propres à chaque type de navire, ou, au contraire, de tendances générales transcendant tous les types de navires en ce qui concerne l'enfoncement. La conclusion est que tous les transits de navires ont un *comportement d'enfoncement semblable, du point de vue qualitatif, mais différent, du point de vue statistique*, peu importe s'il s'agit de transits effectués par un même navire à deux occasions différentes, ou de navires du même type ou de types différents (à l'exception des laquiers classiques, qui semblent moins s'enfoncer que les autres types de navires).

L'analyse a mis en évidence un deuxième résultat marquant : en plus de la valeur moyenne d'enfoncement du navire (calculée à l'aide d'une équation d'enfoncement), il faut tenir compte d'autres phénomènes importants (comme les fluctuations du niveau de l'eau), qui diminuent la profondeur d'eau sous quille disponible. Les chercheurs ont donc élaboré une nouvelle formule qui décrit l'enveloppe maximale des valeurs d'enfoncement mesurées en fonction de la vitesse de déplacement du navire. Cette enveloppe est appelée «équation d'enfoncement dynamique». Donc, l'équation d'enfoncement dynamique tient compte non seulement de l'enfoncement dû au squat comme tel, mais aussi des effets dynamiques qui sont difficiles à isoler du squat. Avec cette approche, il devient superflu de faire une distinction entre les types de navires. Voici donc l'équation qui vaut pour tous les types de navires transitant dans le canal de la Rive-Sud :

$$\text{Enfoncement dynamique (canal)} = 0.0001763\ V^4 + 0.000407\ V^3 - 0.0065785\ V^2 + 0.0821755\ V$$

L'enveloppe pour tous les navires qui transitent dans le lac Saint-Louis est la suivante :

$$\text{Enfoncement dynamique (lac)} = -0.0000229\ V^4 + 0.0017472\ V^3 - 0.016011\ V^2 + 0.0768478\ V,$$

où «enfoncement dynamique» est l'enveloppe d'enfoncement totale maximale (exprimée en mètres) et «V» la vitesse vraie du navire (exprimée en noeuds). Les équations ne sont valides que pour une valeur V maximale de 8 kt dans le canal de la Rive-Sud et de 12 kt dans le lac Saint-Louis. Par exemple, dans le canal de la Rive-Sud, l'enfoncement d'un navire qui transite à une vitesse de 6 kt est normalement de 30 cm environ, mais selon l'équation servant à déterminer l'enveloppe d'enfoncement, il peut occasionnellement présenter un enfoncement total dynamique de 58 cm. À 8 kt, un navire peut occasionnellement afficher un enfoncement dynamique de 116 cm. Dans le lac Saint-Louis, pour le même navire, l'enfoncement dynamique maximal peut atteindre à peine 39 cm à 8 kt, mais 116 cm à 12 kt.

La partie 3 se penche sur les valeurs anormales de profondeur d'eau sous quille dont il est fait état dans le volume 1. Le premier objectif est de cerner toutes les sections critiques de la Voie maritime où des valeurs négatives de profondeur d'eau sous quille ont été établies par F-W-G. Celles-ci sont situées soit dans le canal de la Rive-Sud, soit à l'entrée de l'écluse de Beauharnois (aucune n'est située dans le lac Saint-Louis comme tel). Le deuxième objectif est de vérifier si les valeurs critiques de profondeur d'eau sous quille signifient quelque chose dans la réalité. Pour cela, il faut déterminer si ces valeurs critiques sont liées à des conditions particulières (zones de haut-fond, vitesse excessive du navire, situations de croisement de navires, fluctuations du niveau de l'eau, etc.) ou si elles peuvent être attribuées à des erreurs (GPS, élévation de la quille, élévation du fond du chenal, niveau de l'eau, méthodes de calcul, etc.). La conclusion est que, même si les navires venaient souvent très près de heurter le fond, les valeurs négatives calculées sont probablement toutes fictives. Elles résultent principalement de données bathymétriques contaminées, même si certaines, semble-t-il, sont dues à un «bogue» qui apparaît de temps à autre dans l'algorithme de calcul de la profondeur d'eau sous quille de F-W-G. Les navires s'approchaient du fond en raison de leur vitesse excessive et de fluctuations importantes du niveau de l'eau. Certaines données bathymétriques sont contaminées parce qu'elles viennent de fichiers dont les pics n'ont pas encore été éliminés dans les données brutes des levés.

La partie 4 formule des recommandations pour optimiser la collecte et la réduction des données bathymétriques. Les levés sont faits par une équipe de la CGVMSL. Après une visite sur place, les chercheurs ont recommandé des perfectionnements techniques dont pourrait bénéficier l'équipe. Il est notamment recommandé qu'un projet soit créé en vue de la fourniture systématique de levés bathymétriques et de données sur le niveau de l'eau fiables, précis et efficaces.

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1. INTRODUCTION OF CLASSICAL SQUAT EQUATIONS

The Transportation Development Centre of Transport Canada, on behalf of the St. Lawrence Seaway Management Corporation and its partners, mandated Université Laval (ULaval) to pursue data analysis based on data treated by Fleet Technology Limited, Waterway Simulation Technology Inc., and Géolocation Inc. (F-W-G).The objectives of this section are as follows:

1) Assess the repeatability of squat between two sailings of one ship.
2) Assess the repeatability of squat between ships of one type.
3) Determine whether each ship type has its own squat behaviour or whether there are trends between ship types.

The squat phenomenon is defined as the increase in ship's draft due to combined sinkage and pitch. The sinkage is first defined amidships and then the pitch is applied to determine the squat at the lowest point of the ship. The methodology developed by F-W-G to measure the squat is explained in the report entitled *Maximization of Ship Draft in the St. Lawrence Seaway: Volume 1, Squat Study* (TP 13888E) and will not be summarized herein. However, what is important to understand is that the measurement of squat is not easy to perform and is obviously affected by errors. The important sources of errors are the following. First, a reference elevation for Global Positioning System (GPS) antennas on board the ship was determined in locks (the “zero” procedure) because there is no squat when the ship is at rest. Then, squat values were measured when the ship was in motion using the elevation of GPS antennas with respect to these reference elevations. The “zero” procedure is not easy to conduct successfully since the ship has a vertical movement inside the locks. Therefore, errors on the “zero” affect systematically all squats measured using this vertical reference. This error can easily reach 10 cm or more. A second source of errors is the change in water level. Of course, a correction for the water surface slope between Beauharnois lock and the upstream end of the South Shore Canal was applied. However, there is no way to account for local variations of water level, such as surges, that move the entire ship up or down. The average change of water level in one day for a fixed location in the Seaway is about 20 cm. The “measured” squat values are in fact the maximum squat values of the ship: Sinkage at the midpoint of the ship from the elevation of GPS antennas is first computed and then the squat of the lowest point of the ship is calculated using pitch and roll values. So there may be small numerical errors (difficult to assess) associated with the associated algorithms. Last, there can be some errors of a few centimetres in the elevation measured by GPS antennas on board the ship. Indeed, the accuracy of GPS elevation was estimated at ±10 cm for a 95 percent probability. The addition of all these errors introduces a non-negligible uncertainty associated with the determined squat value.

To assess the repeatability of squat between two sailings of one ship, the four ships that sailed twice were:

1) *Algosar*, days 303 and 316;
2) *CSL Niagara*, days 315 and 320;
3) *John Baird*, days 306 and 314;
4) *Rt. Hon. Paul Martin*, days 299 and 310.

The analysis was performed only for the South Shore Canal and Lake St. Louis sections since these ships were monitored twice only in these two sections of the Seaway; in Lake St. Francis and Wiley-Dondero Canal, there were no ships monitored that sailed twice.

To assess the repeatability of squat between ships of one type, the 23 ships with squat and UKC results supplied by F-W-G were classified according to type:

New Laker (5 passages)

1) *Rt. Hon. Paul Martin* (PMA299 & PMA310)
2) *Algoville* (ALV316)
3) *CSL Niagara* (CNI315 & CNI320)

Traditional Laker (3 passages)

1) *Canadian Voyager* (CAV305)
2) *Manitoulin* (MAN301)
3) *SS Halifax* (HAL308)

Chemical Tanker (3 passages)

1) *Algosar* (ALS303 & ALS316)
2) *Turid Knutson* (TUK317)

Salty Laker (5 passages)

1) *Federal Fugi* (FEF298)
2) *Federal Saguenay* (FSA301)
3) *John B. Aird* (JBA306 & JBA314)
4) *Atlantic Erie* (ATE313)

Salty Bulker (7 passages)

1) *Mariupol* (MAR297)
2) *Zoitsa S* (ZOS302)
3) *Blade Runner* (BLR304)
4) *Fossnes* (FOS304)
5) *Clipper Eagle* (CLE307)
6) *Millenium Raptor* (MIR311)
7) *Lake Carling* (LAC315)

The analysis was also performed only for South Shore Canal and Lake St. Louis sections. For the Lake St. Francis and Wiley-Dondero Canal sections, only four ships were monitored and they were four different types.

To determine whether there are trends between ship types – i.e. comparing ship types – all ships of each type were grouped together for each of the five types. The analysis was performed for all four sections of the Seaway.

The methodology developed to achieve these objectives is the same for all three objectives and is explained in sections 1.1, 1.3 and 1.5. It includes qualitative and quantitative analyses, and findings are presented in sections 1.2, 1.4, and 1.6. Conclusions are stated in section 1.7.

1.1 Performance of Classical Squat: Qualitative Analysis

To explain the steps comprising the qualitative analysis, we start by applying it to the first objective – assess the repeatability of squat between the two sailings of a ship.

We know that the factor that affects squat the most is the speed of the ship through water. For that reason, we first plotted the squat values as a function of ship speed through water and qualitatively compared the plots of the two sailings of one ship. These elements were extracted from F-W-G's squat and under-keel clearance spreadsheets. An example with the ship *Algosar* is given in Figure 1. Even if the range of the squat plotted for each sailing is large (e.g. for ship *Algosar* for day 316 at 6 kn, the squat spreads from about 15 to 50 cm), we can see that they are similar.

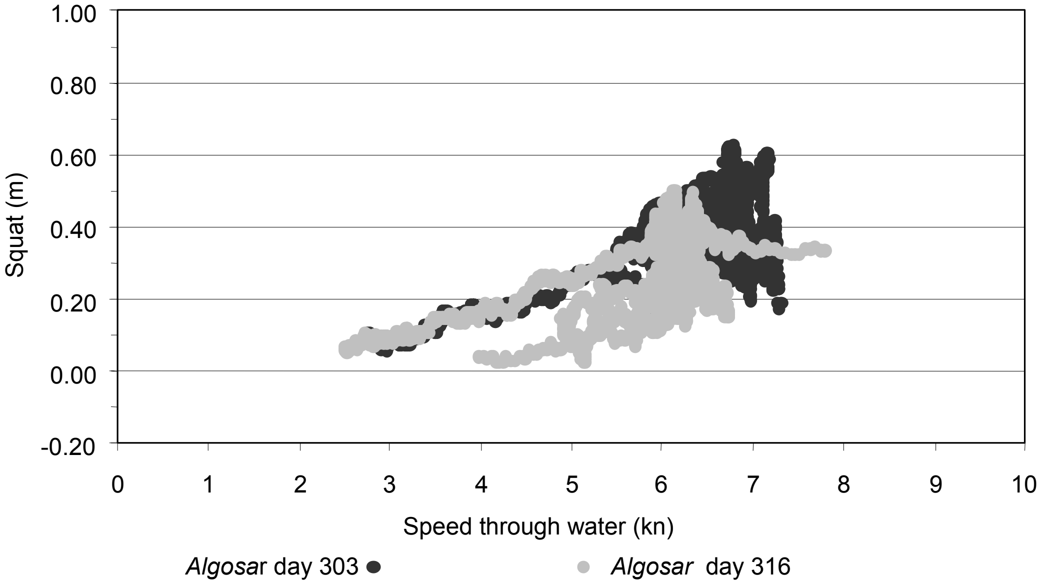

Figure 1 Squat measured as a function of speed through water for ship *Algosar*, South Shore Canal.

However, this comparison is independent of the position of the ship along the channel. In fact, the position of the ship along the channel is important because the squat is also affected by the ratio of the immersed ship cross-section area to the cross-section area of the channel. After the ship's speed, this is the second most important factor that affects squat. To compare the squat measured when the ship is at the same place in the channel, we plotted the squat values as a function of channel station. The channel station is a distance measured along the centreline of the channel from Montreal Harbour: The station is about 2,100 m at St. Lambert lock, 15,600 m at Cote St. Catherine lock, and 48,000 m at Beauharnois lock. An example of the squat as a function of channel station is given in Figure 2. With this kind of plot, the first problem encountered was the difficulty in comparing the squat at a given channel station when the speed of each run was different (i.e. as in Figure 2). Second, for some ships, there were no squat data for the same sectors in the channel (e.g. Figure 3). For these two reasons, we decided to continue our comparisons with the squat as a function of speed through water only.

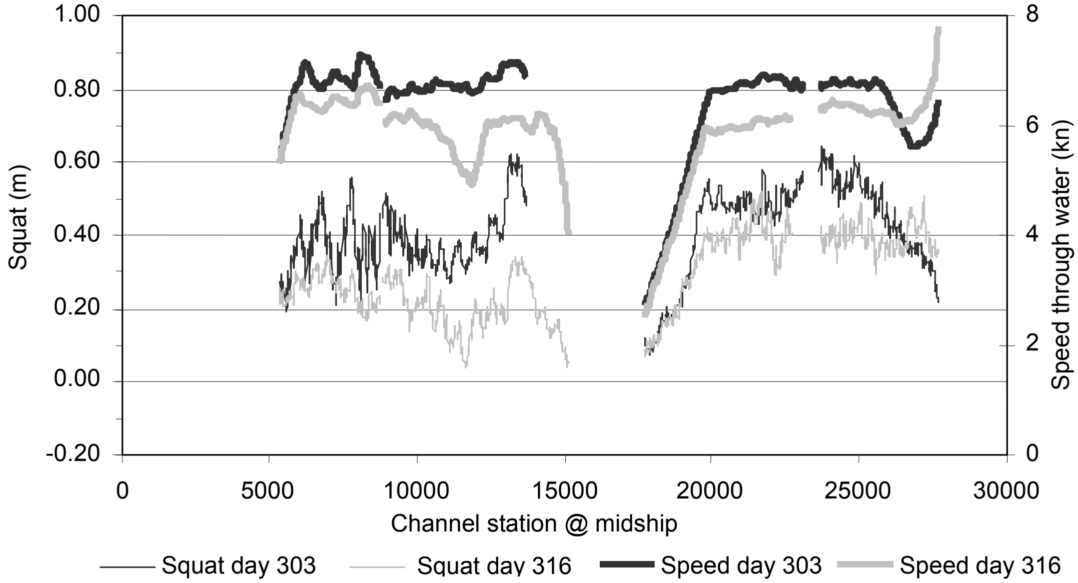

Figure 2 Squat measured as a function of channel station for ship *Algosar*, South Shore Canal.

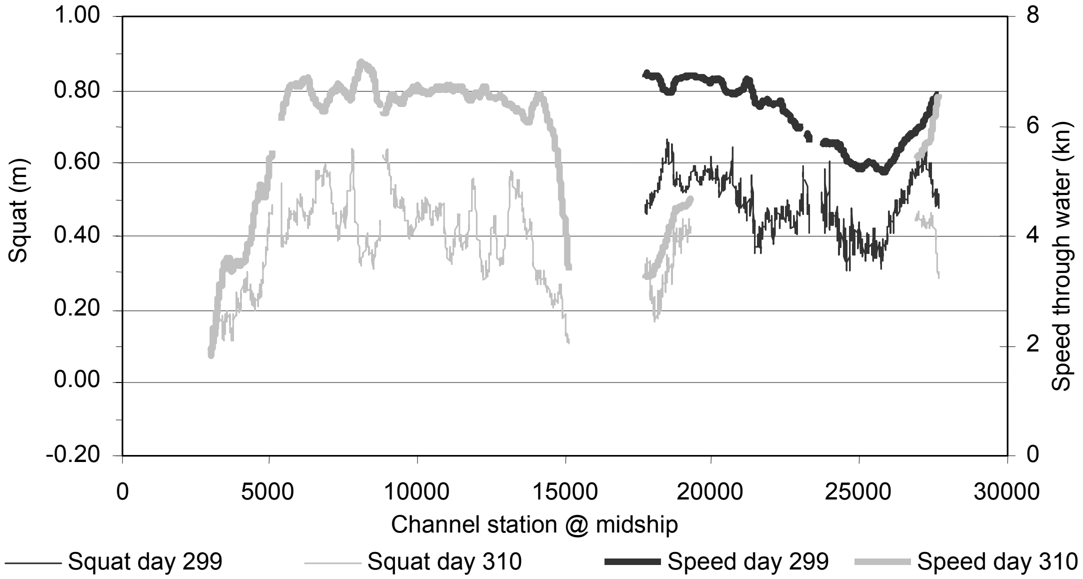

Figure 3 Squat measured as a function of channel station for ship *Rt. Hon. Paul Martin*, South Shore Canal.

We thought that the comparison of squat values as a function of speed could be improved by normalizing the effect of the cross-section area ratio A_{ship}/A_{canal} on squat. This would leave the ship's speed to be the factor that most influences the squat phenomenon. To compute the squat modified for cross-section area ratio, squat was divided by the factor $\left(\frac{A_{\text{immersed ship}}}{A_{\text{canal}}} * \frac{A_{\text{canal standard}}}{A_{\text{ship standard}}}\right)$, where "A" denotes the cross-section area. The coefficient $\left(A_{\text{canal standard}}/A_{\text{ship standard}}\right)$ was used only to normalize the data about the mean squat value. Canal cross-section area was computed using the average of the five channel bottom elevations under the ship, whereas ship's cross-section area was computed using the average draft and does not take into account the increase in draft when the ship is under way. These two cross-section areas were extracted from F-W-G's spreadsheets. The ship's standard cross-section area was the same for all Seaway sections (width = 23.2 m, draft = 7.75 m, midship section coefficient = 0.98; area = 23.2 * 7.75 * 0.98 = 176 m^2). The channel standard cross-section area was 850 m^2 for South Shore Canal, 2,200 m^2 for Lake St. Louis, 2,000 m^2 for Lake St. Francis, and 1,700 m^2 for Wiley-Dondero Canal. An example of the squat modified for the cross-section area ratio is given in Figure 4.

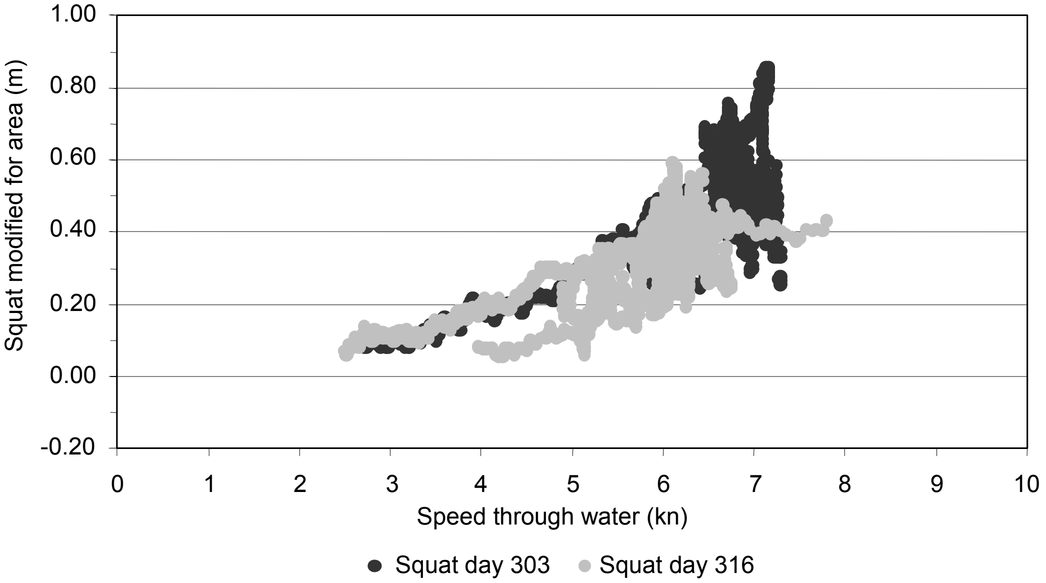

Figure 4 Squat modified for the cross-section area ratio as a function of speed through water for ship *Algosar*, South Shore Canal.

Before plotting the modified squat values, we thought that removing the effect of the cross-section area ratio would narrow the plots (e.g. for ship *Algosar* for day 316 at 6 kn, the squat would spread from 25 to 40 cm instead of 15 to 50 cm). However, the opposite often happened. The modified squat values spread wider than the measured squat values for the same speeds. Moreover, the spreading phenomenon is more important for higher speeds. We know that the ship travels at low speeds only when approaching and leaving locks, and travels at a higher and rather constant speed the rest of the time. Therefore, we have few squat values at low speeds and many squat values at higher speeds. This element, added to the errors in the computed channel cross-section area (e.g. inadequate width or depth, shallow open water in the neighbourhood not taken into account) and to the model's simplification used to remove the cross-section area ratio from the squat, could explain some of the increase of the spread in modified squat values at higher speeds.

Since we were not entirely satisfied with these results, we decided to compare the measured squat with the squat predicted from known models. Each of the three models chosen takes into account the ship's speed and the cross-section area ratio, among others. For each sailing of a ship, the difference between the measured squat and the predicted squat is computed. If the difference is positive, the squat is underestimated by the model; if the difference is negative, the squat is overestimated. The difference between the measured and the predicted squat comes from the errors in the measured squat, the simplicity of the model and real phenomena not accounted for by the model. The Simard, Tuck, and Barrass 2 models were chosen because they predict squat values close to the measured squat values for the South Shore Canal sector most of the time. In addition, they model the ship's speed and the cross-section area ratio differently.

As we examined the models tested by F-W-G in their work, we realized that none of them was giving a good prediction of the squat for all ships and in all four Seaway sectors. For this reason, we tested another model named "Simard". The Simard squat model is the following:

$$S_{max} = h F_{nh}^2 L \tag{1.1}$$

where S_{max} : maximum squat (m)
h : water depth (m)
F_{nh} : Froude number = $V/\sqrt{gh}$
V : ship speed through water (m/s)
g : acceleration of gravity = 9.81 m/s^2
L : channel blockage factor = $0.5\left\{\left[\dfrac{1.01}{1-{TB}/{hW}}\right]^2 - 0.8\right\}$
T : ship static draft (m)
B : ship beam (m)
W : channel width (m)

An example of the squat predicted by the Simard model is given in Figure 5 for South Shore Canal and in Figure 6 for Lake St. Louis.

As can be seen in Figure 6, the Simard model is almost always conservative for the prediction of squat in Lake St. Louis (note that in Figure 5, as everywhere else in this report, the terms "squat" and "maximum squat" mean the same thing because the measured squat is always given for the lowest corner of the ship). In Figure 5, we see that the Simard model usually gives good results for the South Shore Canal sector, although it has more difficulty modelling the squat in the channel between St. Lambert lock and Cote St. Catherine lock (i.e. between channel stations 2100 and 15600). This problem also appears with the Tuck and Barrass 2 squat models, and with the other models tested by F-W-G in their work. In this section of the Seaway, there is an alternation of small islands and shallow open water areas along the channel. This variation in the channel morphology is not accounted for in the computation of the cross-section area of the channel, so the variation does not appear in the predicted squat. Since the ship follows the same path in the channel at a rather constant speed, the same channel morphology errors in the prediction are encountered in each sailing. Therefore, we can compare the two sailings by plotting the differences as a function of ship speed, as in Figure 7. The two plots should be similar if there is repeatability between the two sailings of a ship.

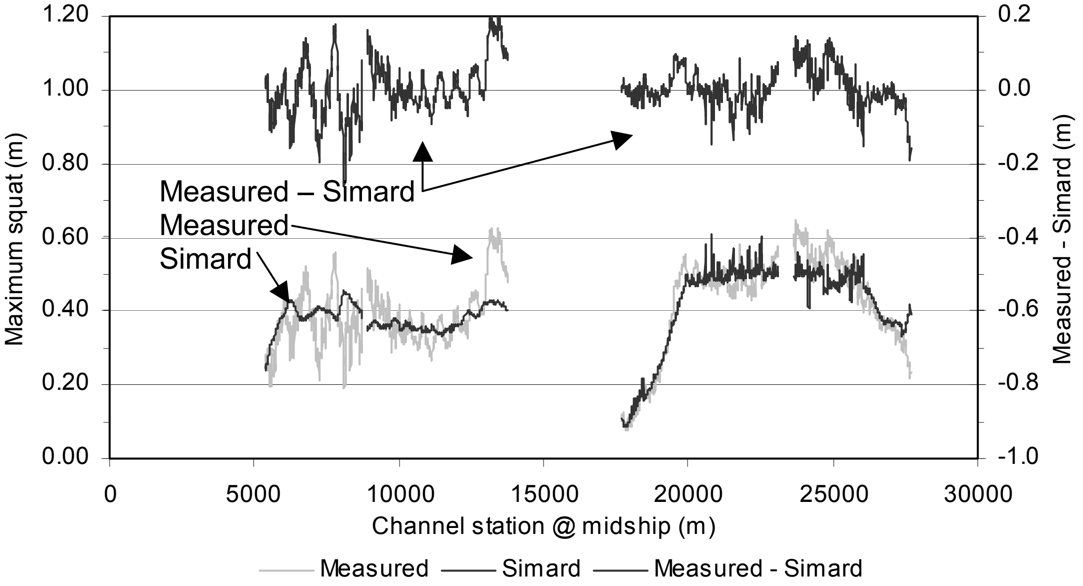

Figure 5 Measured and predicted squat, Simard model, *Algosar*, day 303, South Shore Canal.

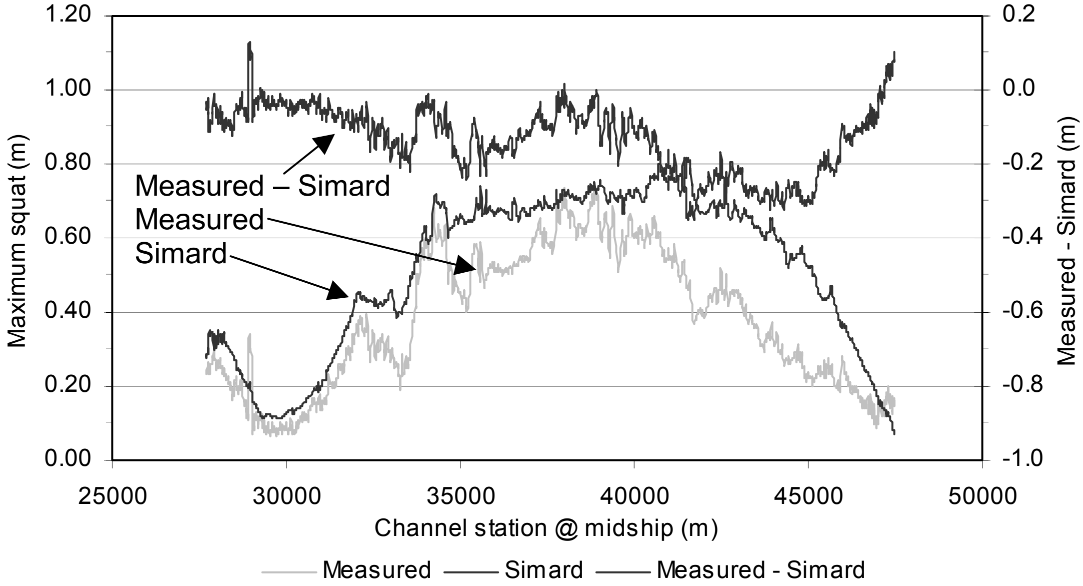

Figure 6 Measured and predicted squat, Simard model, *Algosar*, day 303, Lake St. Louis.

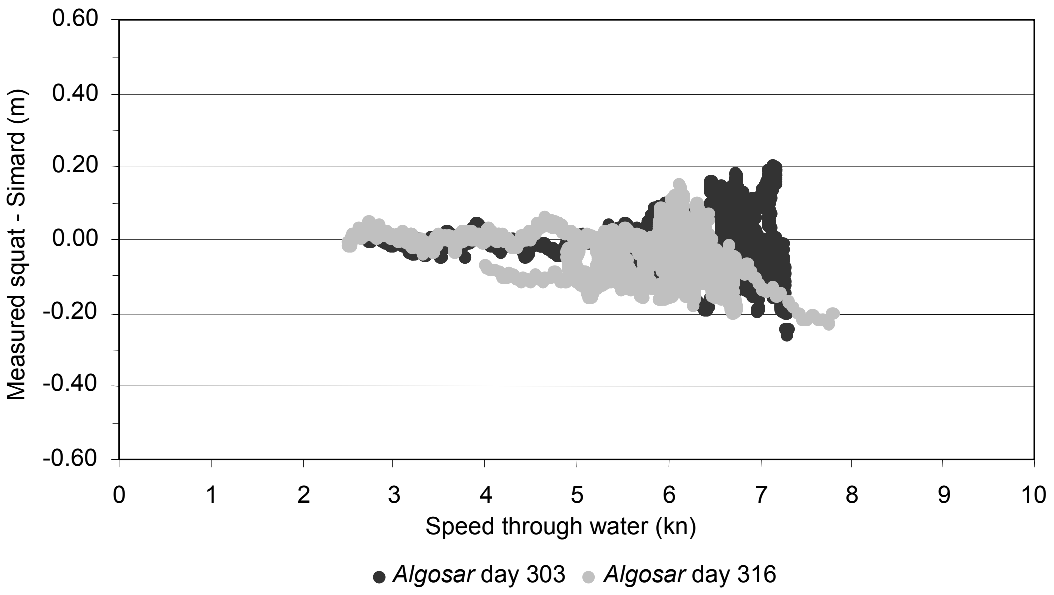

Figure 7 Difference between measured squat and squat predicted by Simard model as a function of speed through water for two sailings of ship *Algosar*, South Shore Canal.

The Tuck model was the second model used to predict squat and to compare two sailings of the same ship. The Tuck squat model is the following:

$$S_b = 1.46 \frac{\nabla}{L_{pp}^2} \frac{F_{nh}^2}{\sqrt{1-F_{nh}^2}} K_S + 0.5L_{pp} \sin\left(\frac{\nabla}{L_{pp}^3} \frac{F_{nh}^2}{\sqrt{1-F_{nh}^2}} K_S\right) \tag{1.2}$$

where
S_b : sinkage at the bow (m)
∇ : ship volumetric displacement (m^3)
L_{pp} : ship length between perpendiculars (m)
F_{nh} : Froude number = $V/\sqrt{gh}$
V : ship speed through water (m/s)
h : water depth (m)
g : acceleration of gravity = 9.81 m/s^2
$K_S = 7.45\,S_i + 0.76$ for $S_i > 0.03$
$K_S = 1$ for $S_i \leq 0.03$
$S_i = A_S / A_C / K_i$
$K_i = 1$ Channel-type parameter for canal with no overbanks

An example of the squat predicted by the Tuck model is given in Figure 8 for South Shore Canal and in Figure 9 for Lake St. Louis.

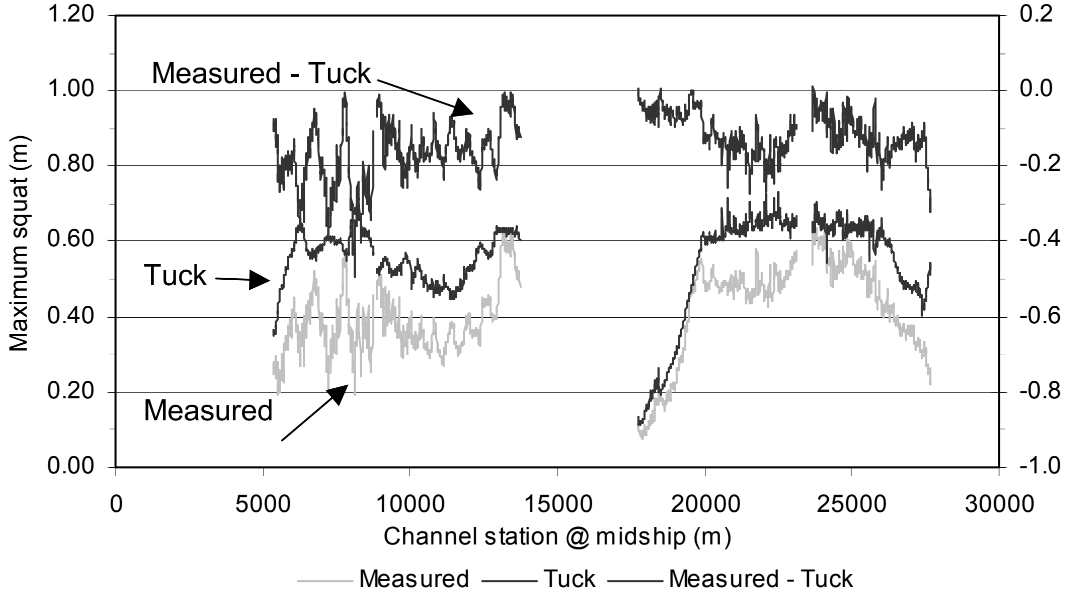

Figure 8 Measured and predicted squat, Tuck model, *Algosar,* day 303, South Shore Canal.

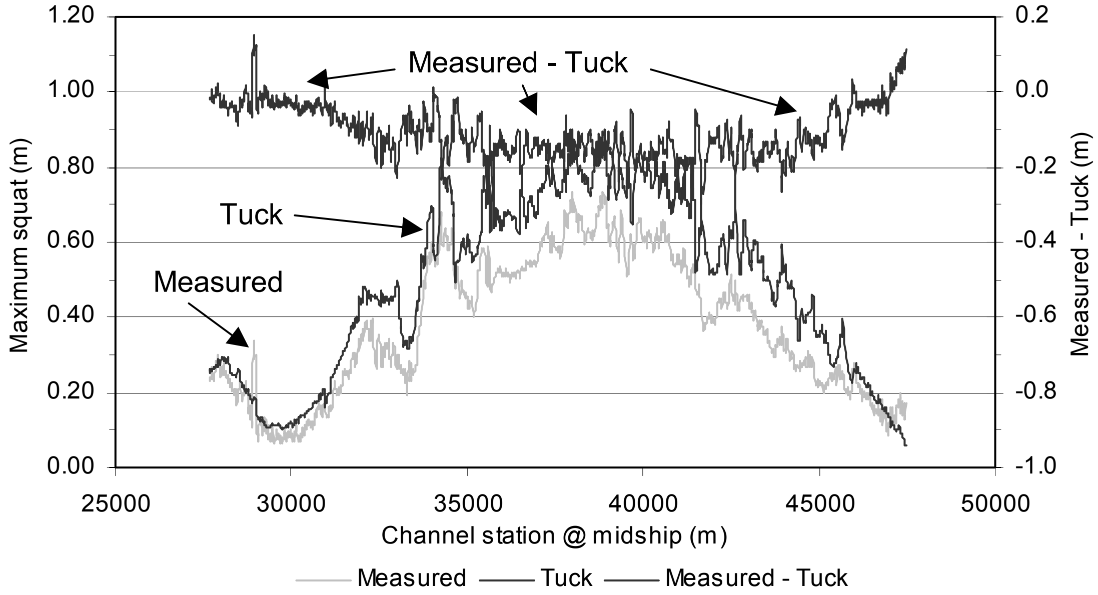

Figure 9 Measured and predicted squat, Tuck model, *Algosar*, day 303, Lake St. Louis.

As can be seen, the Tuck model produces conservative squat values for both the South Shore Canal and the Lake St. Louis sectors. As was previously explained with the Simard model, the comparison of two sailings of a ship is done by plotting the differences between the measured squat and the squat predicted by the Tuck model as a function of ship speed. An example is given in Figure 10 for the South Shore Canal sector.

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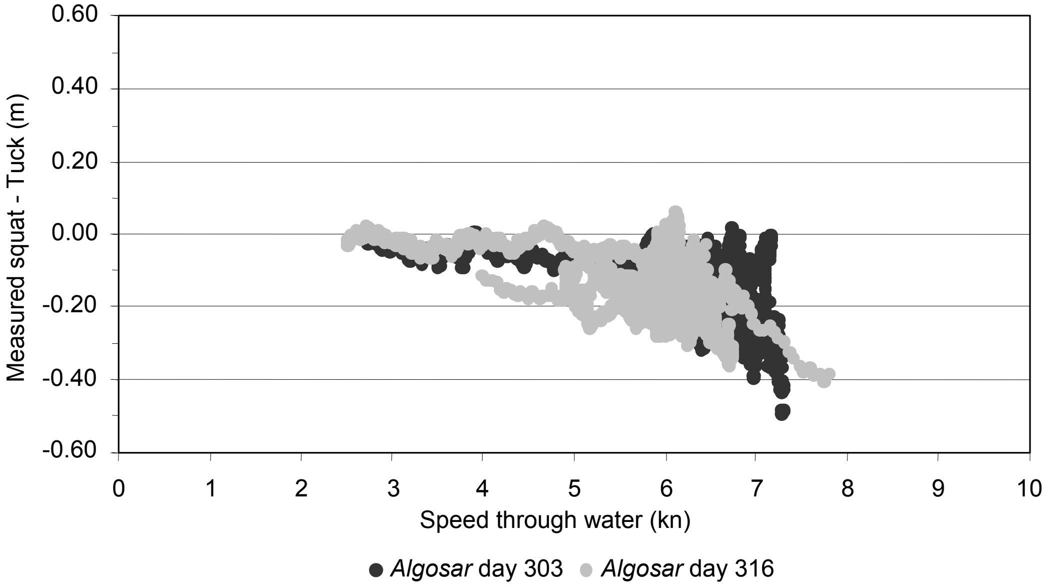

Figure 10 Difference between measured squat and squat predicted by Tuck model as a function of speed through water for two sailings of ship *Algosar*, South Shore Canal.

The third squat model used to predict squat to compare two sailings of the same ship was the Barrass 2 model. This squat model is the following:

$$S_{max} = \frac{C_b \, S_2^{2/3} \, V_k^{2.08}}{30} \tag{1.3}$$

where S_{max} : squat (m)

C_b : ship block coefficient

S_2 : channel blockage = A_s / A_w

A_s : ship underwater cross-sectional area

A_c : channel cross-sectional area

A_w : net underwater channel cross-sectional area = $A_c - A_s$

V_k : ship speed (kn)

An example of the squat predicted by the Barrass 2 model is given in Figure 11 for South Shore Canal and in Figure 12 for Lake St. Louis.

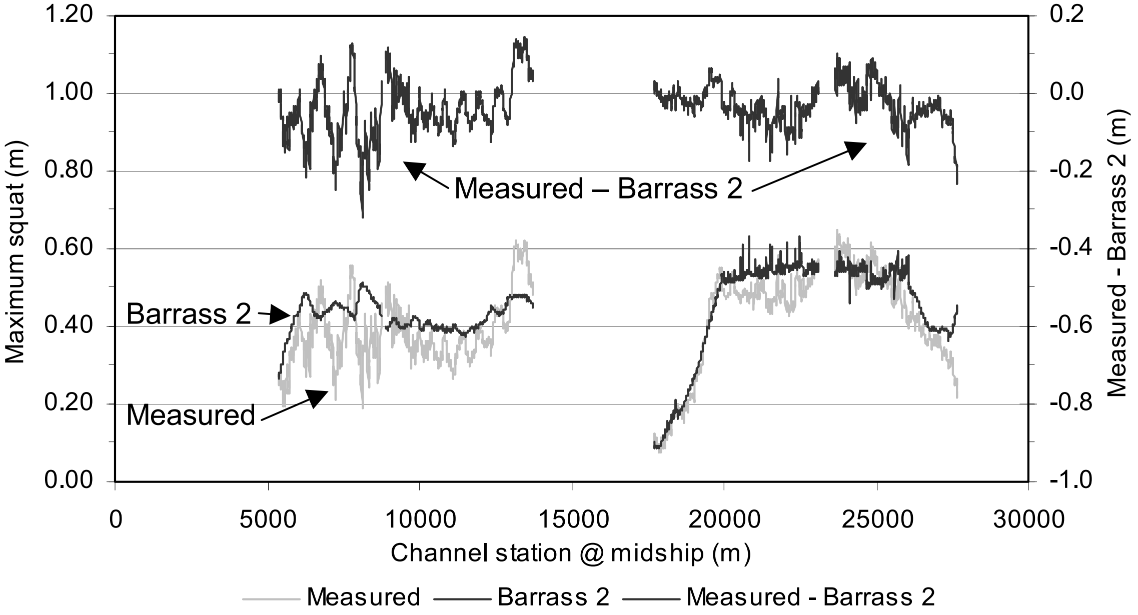

Figure 11 Measured and predicted squat, Barrass 2 model, *Algosar*, day 303, South Shore Canal.

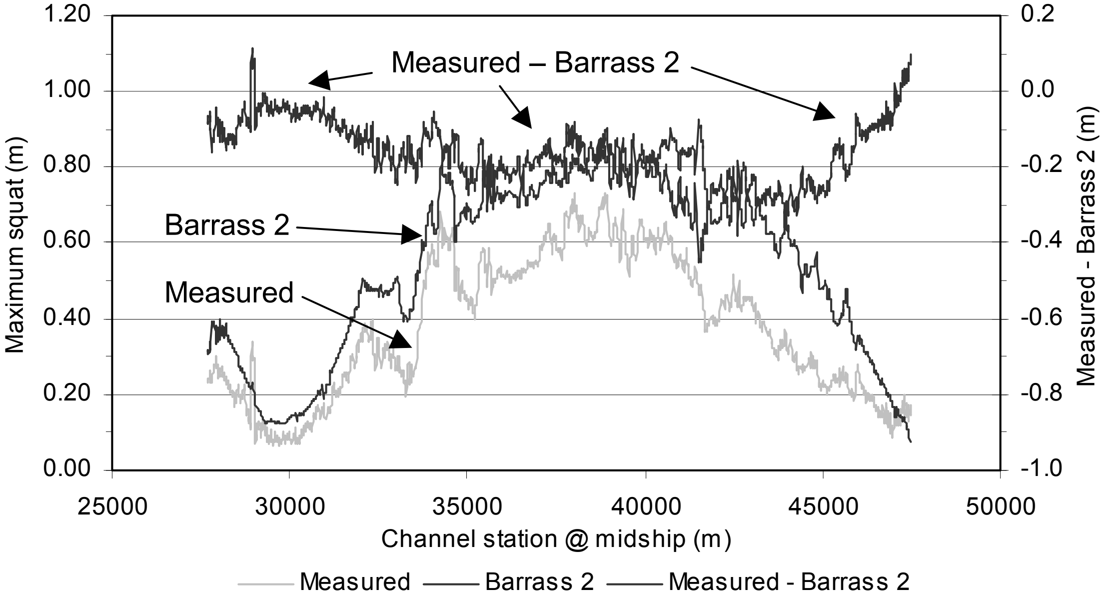

Figure 12 Measured and predicted squat, Barrass 2 model, *Algosar*, day 303, Lake St. Louis.

Squat values predicted by the Barrass 2 model are more conservative in Lake St. Louis than in South Shore Canal. Figure 13 presents the differences between the measured squat and the squat predicted by the Barrass 2 model as a function of ship speed to compare two sailings of a ship.

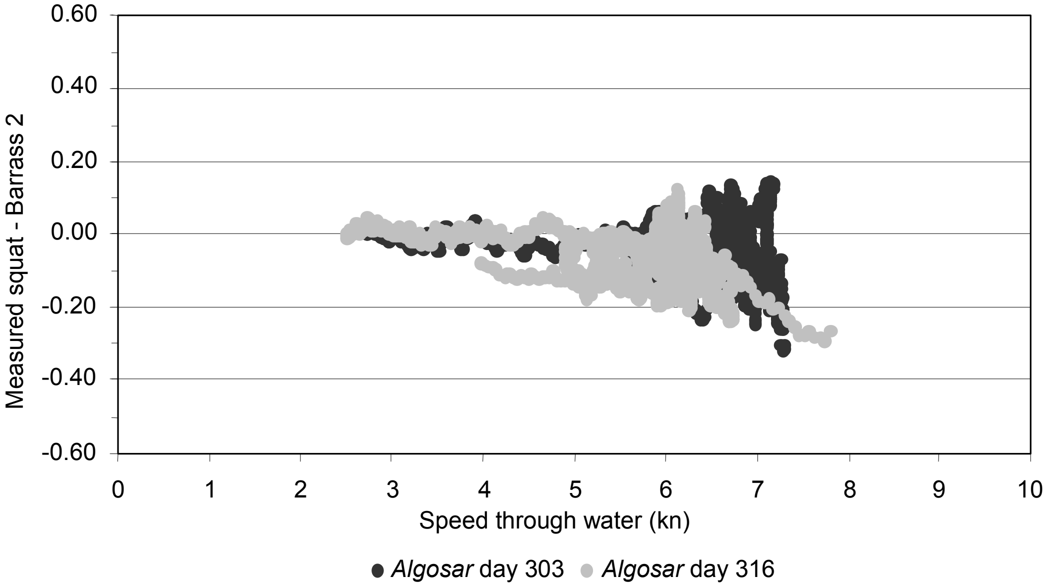

Figure 13 Difference between measured squat and squat predicted by Barrass 2 model as a function of speed through water for two sailings of *Algosar*, South Shore Canal.

As mentioned previously, all these steps were first performed to qualitatively assess the repeatability of squat between two sailings of one ship. The same methodology was used to assess the repeatability of squat between the ships of one type. Finally, the qualitative analysis was performed to determine whether there are trends between ship types. Graphs of results obtained for these two last objectives are not presented in this report, but they virtually identical to those obtained for the first objective (two sailings of the same ship). The findings of this qualitative analysis for these three objectives are presented below.

1.2 Classical Squat: Qualitative Analysis – Findings

All squat data analysed indicate that GPS data used to derive squat is coherent. In other words, the precision of GPS data is sufficient to discern the trend of squat phenomenon and to draw conclusions on its behaviour. Furthermore, F-W-G's data reduction seems to be consistent and appropriate.

For some squat data subsets, theoretical equations (Tuck, Barrass 2 and Simard) tested within this study are in agreement with the measured squat values. As stated in these equations, squat increases as a function of the vessel speed squared and vessel constriction in the channel.

For other squat data subsets, there is a significant difference between predicted and measured squat values. The difference has a systematic behaviour but one that is virtually impossible to describe and/or explain. There seem to be dynamic phenomena that come into play from time to time. These phenomena are related to water level transients discussed further in section 2.

The difference between measured squat and predicted squat with theoretical equations increases as a function of speed (e.g. Figures 7, 10 and 13).

Within the limits mentioned above, our conclusion of the qualitative analysis is that for a specific ship travelling at the same speed through the same sections and on different days, measured squat seems to be the same. In other words, squat behaviour is similar for all the sailings of a ship.

Likewise, ships within the same type have a similar squat behaviour.

Last, ships of different types also have a similar squat behaviour. The only type that could be considered to produce slightly lower squat values than the other types is the Traditional Laker, especially in Lake St. Louis.

1.3 Classical Squat: Quantitative Analysis

In the previous section, we concluded that all the ships' squat behaviours were qualitatively similar from one sailing to the other. However, we needed to quantify this assumption with a systematic analysis. This was done using a standard statistical test on the average. We based our comparison of two ship transits on five elements related to the measured squat:

1) the measured squat as provided by F-W-G (named "raw" in the tests);
2) the squat modified for cross-section area ratio (named "area");
3) the difference between measured squat and squat predicted by the Tuck equation (named "Tuck");
4) the difference between measured squat and squat predicted by the Barrass 2 equation (named "Barrass 2");
5) the difference between measured squat and squat predicted by the Simard equation (named "Simard").

These five elements were expressed as a function of speed through water. The reasons to make the analysis as a function of speed through water were previously mentioned in the description of each element. We decided to use these five elements in our statistical tests to take advantage of the strengths of each one.

The ship's speed through water at each epoch is used to separate each element in one of the four speed classes (e.g. Figure 14). For each of the four Seaway sections, the four speed classes are:

1) South Shore Canal: 0 to 5 kn, 5 to 6 kn, 6 to 7 kn, 7 kn and over
2) Lake St. Louis: 0 to 7 kn, 7 to 9 kn, 9 to 11 kn, 11 kn and over
3) Lake St. Francis: 0 to 8 kn, 8 to 9 kn, 9 to 10 kn, 10 kn and over; in Lake St. Francis, there were no speeds under 6 kn
4) Wiley-Dondero Canal: 0 to 6 kn, 6 to 8 kn, 8 to 10 kn, 10 kn and over.

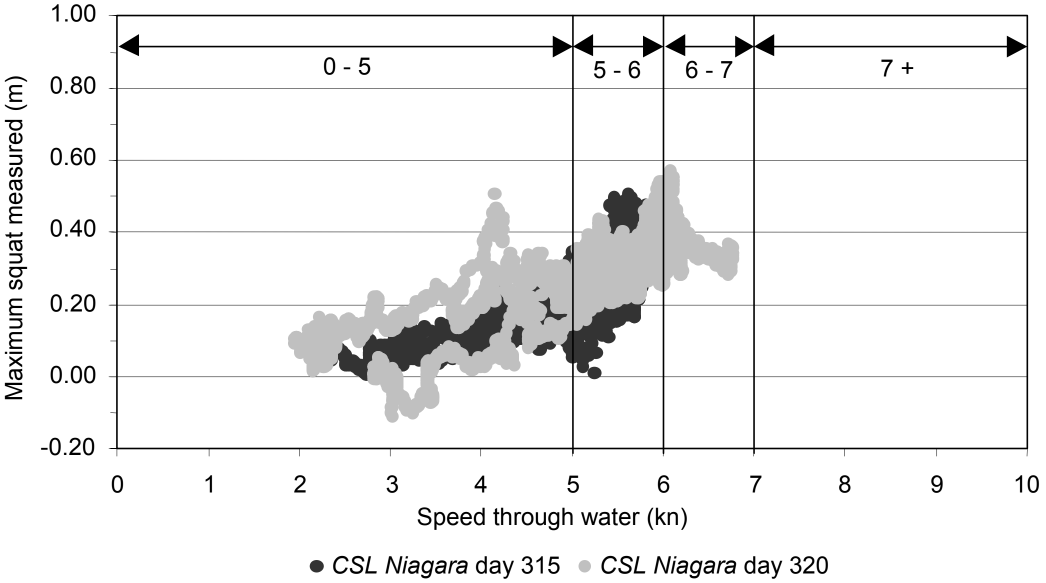

Figure 14 Four speed classes for the measured squat of two sailings of ship *CSL Niagara*, South Shore Canal.

For each ship transit, element and speed class, the average value, standard deviation and sample size were computed (see Tables 1 and 2 for examples). These statistics appear in the following sections of the appendices: A.1 (South Shore Canal) and B.1 (Lake St. Louis) for the assessment of ships passing twice, A.2 (South Shore Canal) and B.2 (Lake St. Louis) for the assessment of ships of the same types, and A.3 (South Shore Canal), B.3 (Lake St. Louis), C.1 (Lake St. Francis) and D.1 (Wiley-Dondero Canal) for the assessment of trends between ship types.

Table 1 Average (avg), standard deviation (std) and sample size (nb) values computed for each speed class for each element for day 303 of ship *Algosar*, South Shore Canal. Average and standard deviation are expressed in metres.

	0 - 5	5 - 6	6 - 7	7 +
raw	avg = 0.15 std = 0.05 nb = 319	avg = 0.34 std = 0.05 nb = 281	avg = 0.44 std = 0.09 nb = 1799	avg = 0.43 std = 0.12 nb = 217
area	avg = 0.15 std = 0.05 nb = 319	avg = 0.35 std = 0.04 nb = 281	avg = 0.52 std = 0.08 nb = 1799	avg = 0.59 std = 0.17 nb = 217
Tuck	avg = -0.05 std = 0.02 nb = 319	avg = -0.11 std = 0.04 nb = 281	avg = -0.15 std = 0.06 nb = 1799	avg = -0.20 std = 0.13 nb = 217
Barrass 2	avg = -0.01 std = 0.02 nb = 319	avg = -0.03 std = 0.03 nb = 281	avg = -0.04 std = 0.06 nb = 1799	avg = -0.05 std = 0.13 nb = 217
Simard	avg = -0.01 std = 0.02 nb = 319	avg = -0.01 std = 0.03 nb = 281	avg = 0.01 std = 0.06 nb = 1799	avg = 0.01 std = 0.13 nb = 217

Table 2 Average (avg), standard deviation (std) and sample size (nb) values computed for each speed class for each element for day 316 of ship *Algosar*, South Shore Canal. Average and standard deviation are expressed in metres.

	0 - 5	5 - 6	6 - 7	7 +
raw	avg = 0.15 std = 0.06 nb = 413	avg = 0.25 std = 0.12 nb = 771	avg = 0.32 std = 0.09 nb = 1787	avg = 0.35 std = 0.01 nb = 15
area	avg = 0.16 std = 0.07 nb = 413	avg = 0.30 std = 0.10 nb = 771	avg = 0.38 std = 0.07 nb = 1787	avg = 0.40 std = 0.01 nb = 15
Tuck	avg = -0.04 std = 0.04 nb = 413	avg = -0.12 std = 0.07 nb = 771	avg = -0.16 std = 0.07 nb = 1787	avg = -0.33 std = 0.05 nb = 15
Barrass 2	avg = -0.01 std = 0.04 nb = 413	avg = -0.07 std = 0.06 nb = 771	avg = -0.08 std = 0.06 nb = 1787	avg = -0.24 std = 0.04 nb = 15
Simard	avg = -0.00 std = 0.03 nb = 413	avg = -0.04 std = 0.07 nb = 771	avg = -0.04 std = 0.06 nb = 1787	avg = -0.19 std = 0.04 nb = 15

1.4 Classical Squat: Quantitative Analysis – Findings

In most cases, the standard deviation of each sample of an element increases as a function of speed class. For instance, the standard deviation of speed class "7 +" is superior than "0 - 5" for each of the five elements related to measured squat.

Generally, removing the effect of the cross-section area ratio from the measured squat produces no significant gain on the standard deviation of each sample.

The three squat models (Tuck, Barrass 2 and Simard) used in this study were considered to be the most adequate models. These statistics show that they perform equally well (i.e. none of these models is significantly superior to the two others in terms of their standard deviation of the residuals).

The use of these equations to model squat diminishes standard deviations by up to 30 to 50 percent with respect to measured squat. However, because of unmodelled phenomena (particularly at high speeds), the residuals still have relatively high standard deviations of up to 12 to 15 cm.

1.5 Classical Squat: Repeatability Tests

Once the basic statistics (average ($\overline{X}$), standard deviation (s) and sample size (n)) of each separate sailing were determined, tests were performed using the two sets. The objective of the statistical tests was to determine whether two samples have statistically the same average: i.e. whether they come from the same population ($\mu_1 - \mu_2 = 0$; μ is the average of the population), or whether they are different. This enables us to state, for instance, whether ship *Algosar* is considered to have had the same squat behaviour for its two sailings or whether the squat behaviour is considered different. The test on average is always done between two transits on each of the five squat-related elements for each speed class separately. The relationship used to state whether two averages are the same or different is the following:

$$Z_{\mathrm{exp}} = \frac{(\overline{X}_1 - \overline{X}_2) - (\mu_1 - \mu_2)}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}} \tag{1.4}$$

where the starting hypothesis is $H_0 : \mu_1 - \mu_2 = 0$ ("pass")

and the alternative hypothesis is $H_1 : \mu_1 - \mu_2 \neq 0$ ("fail")

The Z_{exp} value is then compared to the known values of the Normal distribution for a 95 percent probability. The starting hypothesis – i.e. the two averages come from the same population – is accepted if $-1.96 \leq Z_{\mathrm{exp}} \leq 1.96$ and rejected otherwise. In that case, the alternative hypothesis states that the two averages are not statistically the same and do not come from the same population. The further Z_{exp} is from the $[-1.96, 1.96]$ interval, the more different the averages are from each other. (For these tests, there must be at least 30 observations.)

Table 3 is an example of the results obtained for the statistical test of two sailings (days 303 and 316) of ship *Algosar*. The Z_{exp} value of the test is given with a “pass” or “fail” success result. The average, standard deviation and sample size values used to compute Z_{exp} with Equation 1.4 are the ones presented in Tables 1 and 2. Three examples are given below for better understanding of the results shown in Table 3.

First, the statistical test performed on the measured squat (raw) of speed class 0 - 5 kn between sailings of days 303 and 316 of ship *Algosar* gives “0.25 pass” as a result, which is the value computed for Z_{exp} using the average, standard deviation and sample size of raw and 0 - 5 kn of sailings 303 and 316 of ship *Algosar*. The term “pass” means that Z_{exp} was inside the limits $[-1.96, 1.96]$, so the starting hypothesis is accepted and the test is successful for the speed class 0 - 5 kn of raw squat. Second, for the speed class 7 + kn, it is written “n<30” instead of the results of the statistical tests. As mentioned previously, there must be at least 30 observations in each sample to perform the test. When one of the samples is smaller than 30, the note "n<30" appears instead of the result of Z_{exp}. Third, the statistical test done on the difference between the measured squat and the prediction from the Barrass 2 equation (Barrass 2) of speed class 6 - 7 kn between the two sailings gives “19.30 fail” as result. Since $Z_{exp} = 19.30$ is outside the limits $[-1.96, 1.96]$, the starting hypothesis is rejected for the speed class 6 - 7 kn of Barrass 2 element and the test fails. If the starting hypothesis is rejected for the majority of the five squat-related elements and four speed classes, it can be stated that the ship does not give the same squat values for two sailings under the same operating conditions.

Table 3 Results of statistical tests on the average between days 303 and 316 of ship *Algosar*, South Shore Canal.

		0 - 5	5 - 6	6 - 7	7 +
als303 &	raw	0.25 pass	17.78 fail	39.79 fail	n<30
als316	area	-2.58 fail	11.01 fail	53.33 fail	n<30
	Tuck	-5.12 fail	4.41 fail	6.52 fail	n<30
	Barrass 2	-2.76 fail	11.14 fail	19.30 fail	n<30
	Simard	-3.02 fail	11.68 fail	25.73 fail	n<30

The results of the statistical analysis performed to assess the repeatability of squat between two sailings of one ship are presented in the following sections of the appendices: E.1 for South Shore Canal and F.1 for Lake St. Louis.

The statistical analysis was also performed for each ship type to assess the repeatability of squat between ships of one type. The results are presented in the following sections of the appendices: E.2 for South Shore Canal and F.2 for Lake St. Louis. The statistical test on averages is performed with two ships at the same time, so all ship combinations within one type appear in the results.

Finally, the statistical analysis was performed to determine whether there are trends between ship types – i.e. comparing ship types. The analysis was done for the four sections of the Seaway: South Shore Canal (section E.3), Lake St. Louis (section F.3), Lake St. Francis (section G.1), and Wiley-Dondero Canal (section H.1).

1.6 Classical Squat: Repeatability Tests – Findings

When we apply standard statistical tests to compare one ship sailing to another, the finding is virtually always the same; from a statistical point of view, the squat phenomenon of each transit is unique. In other words, squat behaviour from one sailing to the next is always different. This regardless of whether it is the same ship passing on different days, two ships of the same type passing on the same day, or two ships of different types.

How can we explain this result when, qualitatively (section 1.1), we found that the squat behaviour from one sailing to the next (with a possible exception for Traditional Lakers) is very similar? There are two important factors:

1) The first is numerical. The statistical test on the average values uses the sample size of each sample in its calculation (see Equation 1.4). Since each sample size is often large – e.g. over 200 observations – it leads to a small number at the denominator of Z_{exp}. Consequently, the average of each sample must be the same within a few millimetres to obtain Z_{exp} inside $[-1.96, 1.96]$ and thus a successful result.

2) The second relates to systematic errors. As discussed at the beginning of section 1, the precision of squat values used in this project is degraded by errors that may be undetected. These errors can be the zero determination of the antennas from one sailing to the next; the change in water slope and/or elevations from one sailing to the next; ship buoyancy characteristics from one sailing to the next; or GPS satellite and antenna configuration, ionosphere degradation and data reduction from one sailing to the next. These systematic errors are small enough not to affect the general trend of squat values. Nevertheless, they are significant enough to affect the average values used in the statistical test and therefore the result of the test.

1.7 Classical Squat: Conclusions

Qualitatively speaking, squat behaviour seems similar from one sailing to the next (with the possible exception of Traditional Lakers). Statistically speaking, it is the opposite – i.e. each sailing is dissimilar. However, both points of view agree on one thing: there is some systematic and unexplained behaviour going on. It shows up as a function of speed in both the standard deviation and the average. Therefore, the conclusions for the objectives stated at the beginning are:

1) Repeatability of squat between two sailings of the same ship: squat behaviour is *qualitatively similar but statistically different* for all sailings of a ship.

2) Repeatability of squat between ships of one type: ships within the same type have a *qualitatively similar but statistically different* squat behaviour.

3) Trends between ship types: all ship types have *qualitatively similar but statistically different* trends. In other words, ships of different types have a similar squat behaviour. The only type that could be considered to produce slightly lower squat values than the other types is the Traditional Laker, especially in Lake St. Louis.

Given the similarity in squat behaviour but the significant variations in sinkage over and above modelled squat behaviour, we developed an alternative way of looking at the data. It is based on determining the upper envelope of the squat behaviour rather than seeking equations to describe the mean. Using this approach, it may be unnecessary to distinguish between ship types. We therefore determined an equation that fits all ship types for South Shore Canal (Equation 2.1) and another one for Lake St. Louis (Equation 2.6) as well as individual equations for each ship type. More explanations are given in section 2.

2. INTRODUCTION OF DYNAMIC SQUAT EQUATIONS

To achieve safe navigation and under-keel clearance, the equations chosen to model the squat phenomenon must be conservative. To do so, these equations must take into account not only the squat itself, but also the dynamic effects that are difficult to separate from squat. The dynamic effects can introduce additional sinkage and include local changes in water surface elevation, surges, quick changes in rudder and propeller ship manoeuvres, variable channel morphology, ship roll, pitch and heave, and ship meetings, among others. As a result, the squat equations are rather called "dynamic squat" equations and are expressed as a function of ship speed-through-water only. It must be noted that the dynamic squat equations are representative of an envelope of the data and do not represent the most extreme sinkage observations. Therefore, in few cases, the observed dynamic squat can be superior to that calculated using the proposed equation (see Figures 15 to 23).

Sections 2.1 to 2.9 present the equations selected to model dynamic squat. A set of equations is given for the South Shore Canal section and another for the Lake St. Louis section. As a matter of fact, these two sections have different channel configurations: the South Shore Canal is a confined water (shallow and narrow) whereas Lake St. Louis is a semi-open water channel type. Since ships squat more in confined water than in open water channel types, using only the South Shore Canal equation would overestimate dynamic squat in Lake St. Louis.

A dynamic squat equation for all ship types is given for each of these two sections of the Seaway. In our view, this is the equation that should be inserted in the Seaway's spreadsheet for regular navigation. However, for special cases – e.g. the draft of a ship is slightly over the permissible limit – the maximum permissible vessel speed could be computed with respect to the specific type of the ship using the equation provided below for that specific ship type.

For Lake St. Francis and Wiley-Dondero Canal, no dynamic squat equations were determined because only four ships were monitored.

2.1 Dynamic Squat Equation for All Ship Types (South Shore Canal)

$$\text{Dynamic squat} = 0.0001763 * V^4 + 0.000407 * V^3 - 0.0065785 * V^2 + 0.0821755 * V \quad (2.1)$$

where V is the speed through water (kn) and Dynamic squat is the maximum total sinkage value (m).

This equation is valid for speeds from 0 to 8 kn. It should not be used for speeds exceeding 8 kn (extrapolation) because the behaviour of the equation is unknown. This is the consequence of not using squat values at speeds above 8 kn in the determination of the equation. Since the dynamic squat equation for all ship types is more conservative than all the equations for each type, it can therefore be used for ships of all types. The dynamic squat values obtained with the present equation are illustrated on Figure 15.

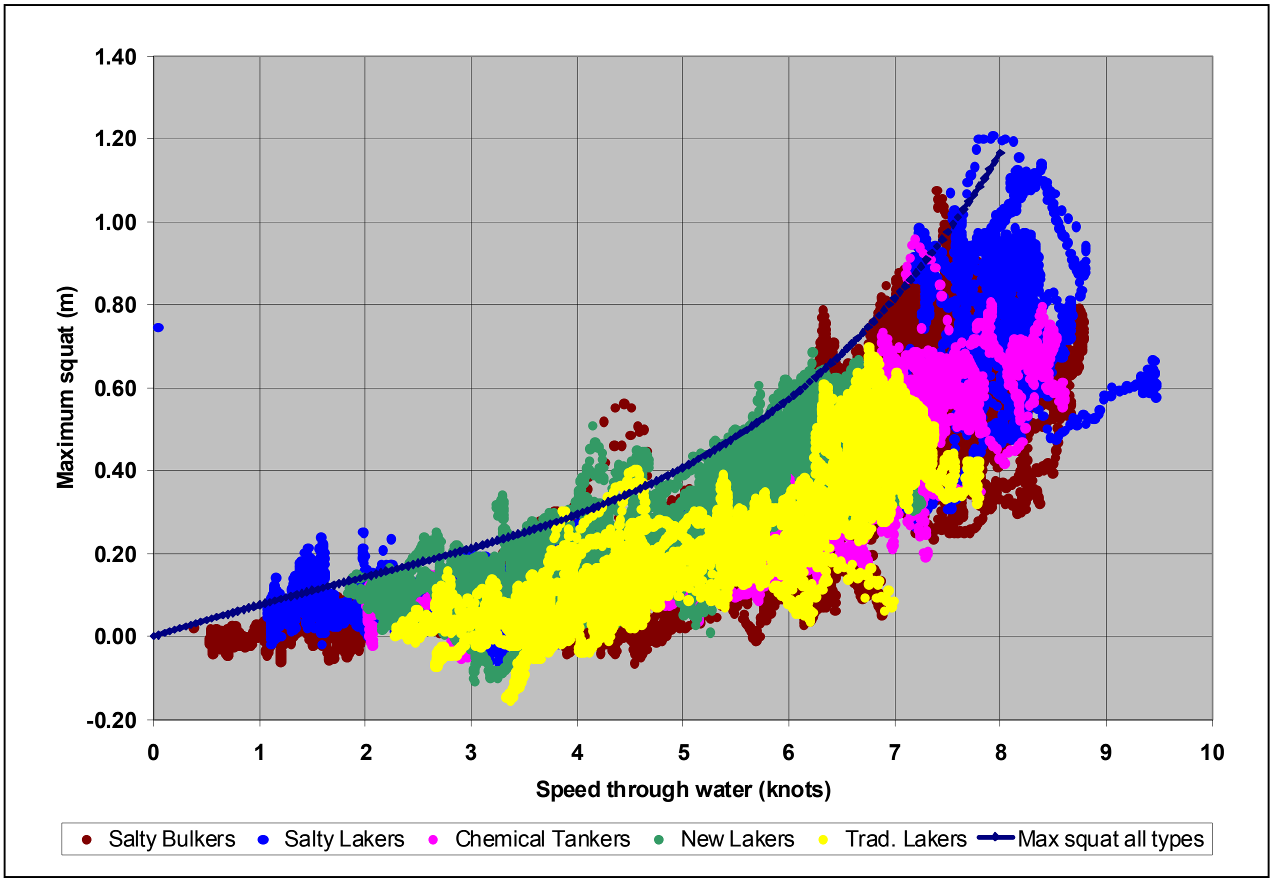

Figure 15 Dynamic squat values with the equation for all types, South Shore Canal.

2.2 Dynamic Squat Equation for Traditional Laker Type (South Shore Canal)

$$\text{Dynamic squat} = 0.0003035 * V^4 - 0.0021286 * V^3 + 0.0089056 * V^2 + 0.0289864 * V \quad (2.2)$$

This equation is valid for speeds from 0 to 7 kn. If some ships of that type exceed 7 kn, it is recommended to use the dynamic squat equation for all types. The dynamic squat values obtained with the equation for Traditional Lakers are illustrated in Figure 16.

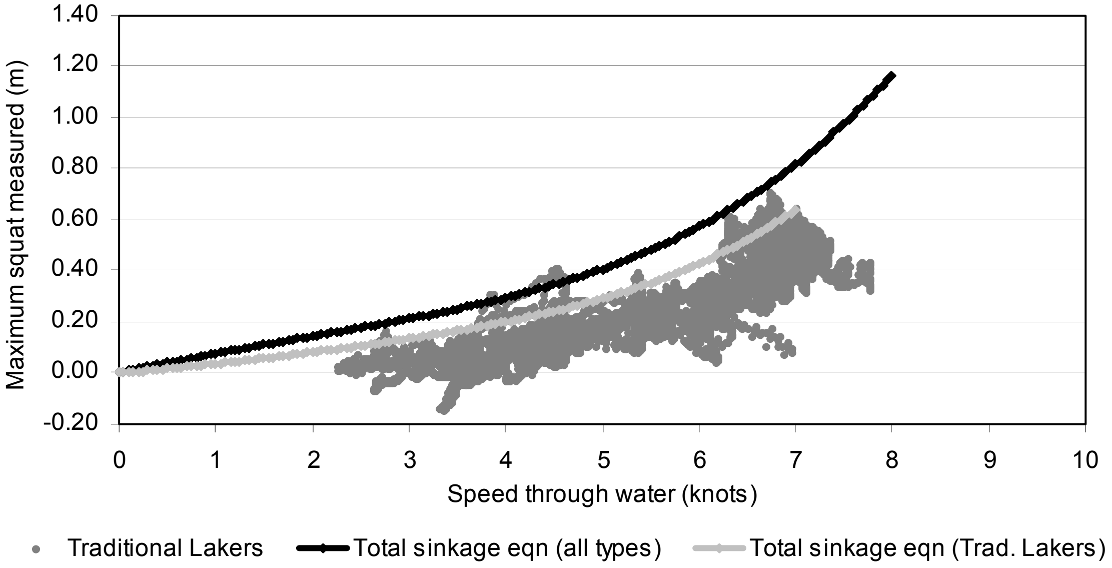

Figure 16 Dynamic squat values with the equation for Traditional Lakers, South Shore Canal.

2.3 Dynamic Squat Equation for Chemical Tanker Type (South Shore Canal)

$$\text{Dynamic squat} = -0.0004077 * V^4 + 0.0079021 * V^3 - 0.0334612 * V^2 + 0.083439 * V \quad (2.3)$$

This equation is valid for <u>speeds from 0 to 8 kn</u>. The dynamic squat values obtained with the equation for Chemical Tankers are illustrated in Figure 17.

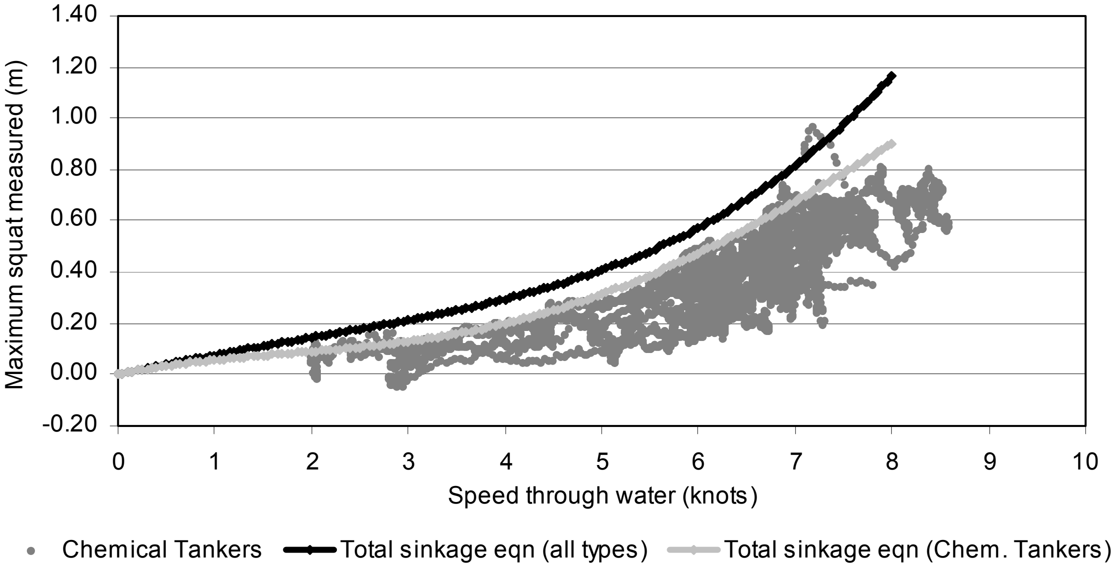

Figure 17 Dynamic squat values with the equation for Chemical Tankers, South Shore Canal.

2.4 Dynamic Squat Equation for Salty Laker Type (South Shore Canal)

$$\text{Dynamic squat} = -0.0000972 * V^4 + 0.0052199 * V^3 - 0.0318266 * V^2 + 0.111191 * V \quad (2.4)$$

This equation is valid for speeds from 0 to 8 kn. The dynamic squat values obtained with the equation for Salty Lakers are illustrated in Figure 18.

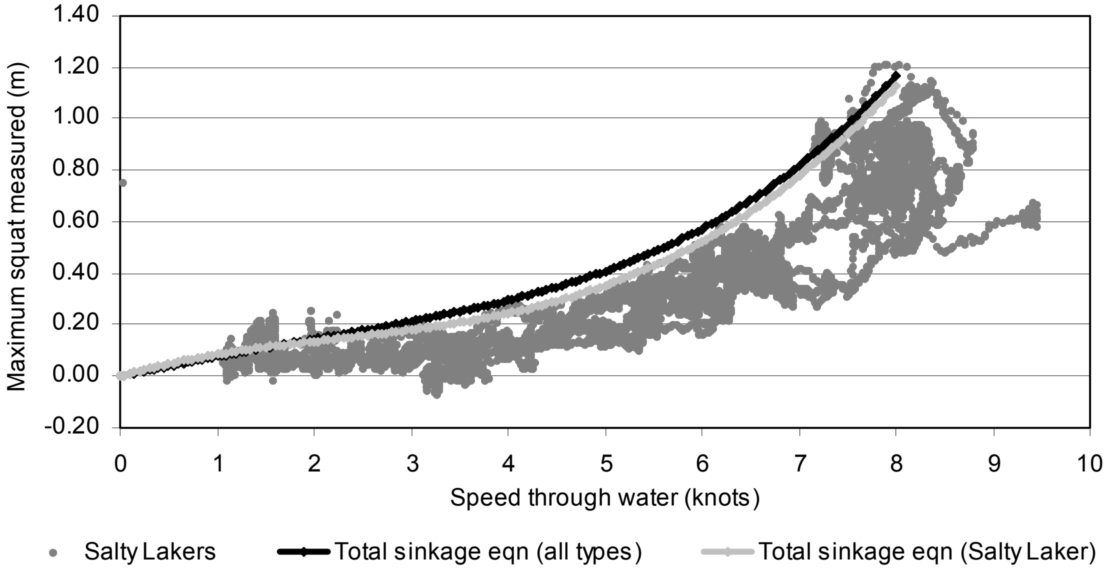

Figure 18 Dynamic squat values with the equation for Salty Lakers, South Shore Canal.

2.5 Dynamic Squat Equation for Salty Bulker Type (South Shore Canal)

$$\text{Dynamic squat} = -0.0001364 * V^4 + 0.00559 * V^3 - 0.0286669 * V^2 + 0.0878583 * V \quad (2.5)$$

This equation is valid for speeds from 0 to 8 kn. The dynamic squat values obtained with the equation for Salty Bulkers are illustrated in Figure 19.

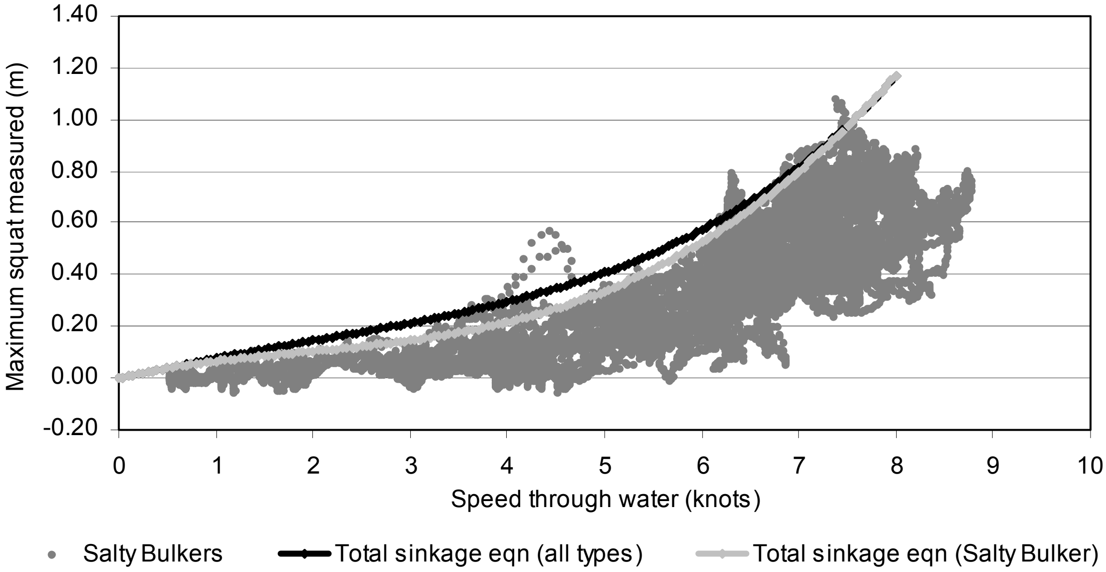

Figure 19 Dynamic squat values with the equation for Salty Bulkers, South Shore Canal.

2.6 Dynamic Squat Equation for All Ship Types (Lake St. Louis)

$$\text{Dynamic squat} = -0.0000229 * V^4 + 0.0017472 * V^3 - 0.016011 * V^2 + 0.0768478 * V \quad (2.6)$$

where V is the speed through water (kn) and Dynamic squat is the maximum total sinkage value (m).

This equation is <u>valid for speeds from 0 to 12 kn</u>. It should not be used for speeds exceeding 12 kn (extrapolation) because the behaviour of the equation is unknown. This is the consequence of not using squat values at speeds above 12 kn in the determination of the equation. Since the dynamic squat equation for all ship types is more conservative than all the equations for each type, it can therefore be used for ships of all types. The dynamic squat values obtained with the equation for all types are illustrated in Figure 20.

The dynamic squat equation for Chemical Tanker and Salty Bulker types is the same as the one for all types.

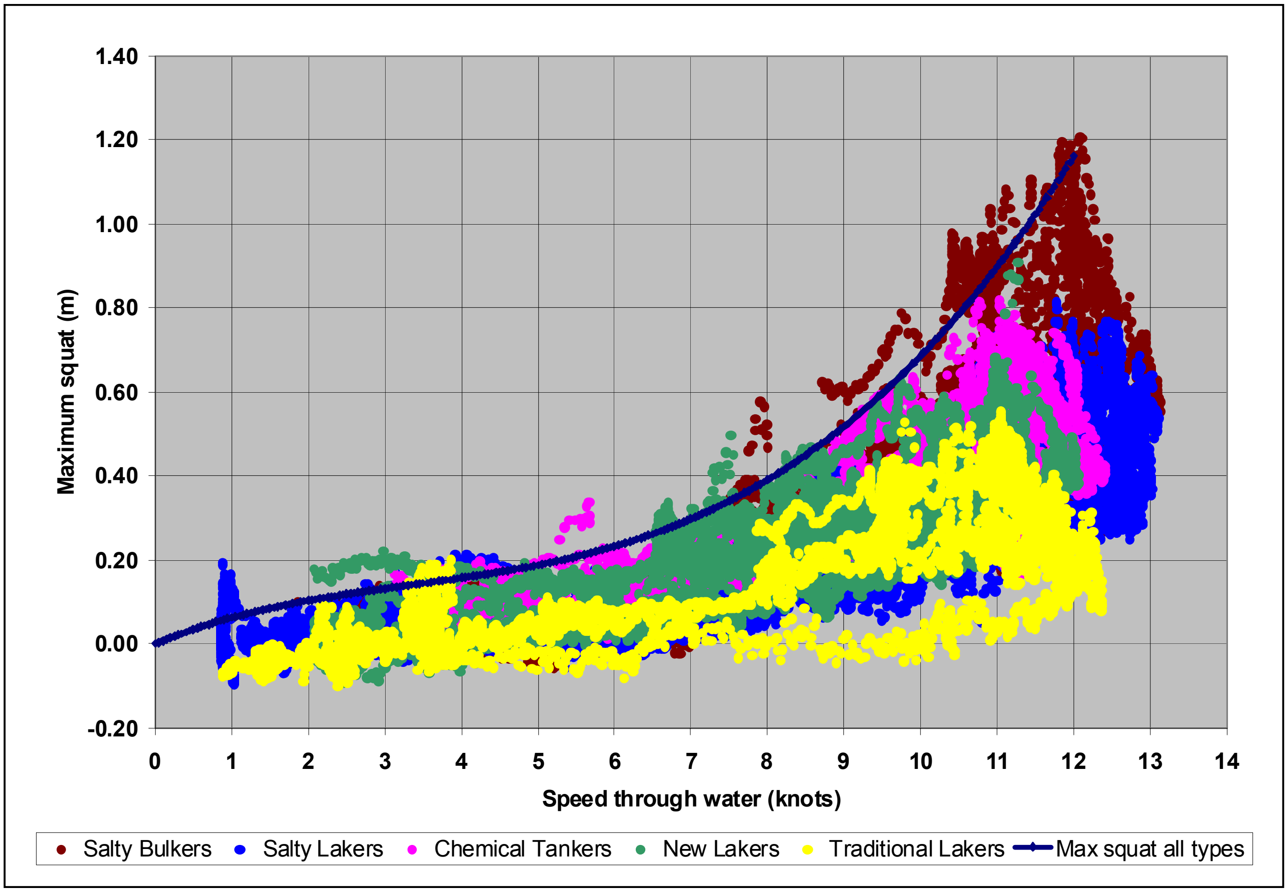

Figure 20 Dynamic squat values with the equation for all types, Lake St. Louis.

2.7 Dynamic Squat Equation for New Laker Type (Lake St. Louis)

$$\text{Dynamic squat} = -0.000075 * V^4 + 0.0021552 * V^3 - 0.0156176 * V^2 + 0.0725598 * V \quad (2.7)$$

This equation is valid for speeds from 0 to 12 kn. The dynamic squat values obtained with the equation for New Lakers are illustrated in Figure 21.

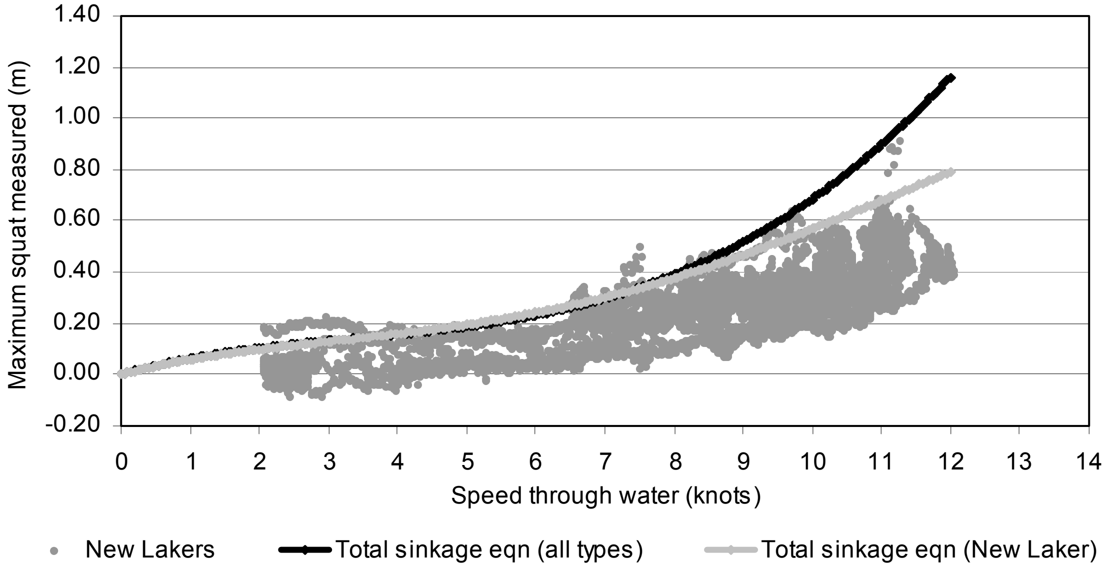

Figure 21 Dynamic squat values with the equation for New Lakers, Lake St. Louis.

2.8 Dynamic Squat Equation for Traditional Laker Type (Lake St. Louis)

$$\text{Dynamic squat} = -0.0001007 * V^4 + 0.002602 * V^3 - 0.016014 * V^2 + 0.0429744 * V \quad (2.8)$$

This equation is valid for <u>speeds from 0 to 12 kn</u>. The dynamic squat values obtained with the equation for Traditional Lakers are illustrated in Figure 22.

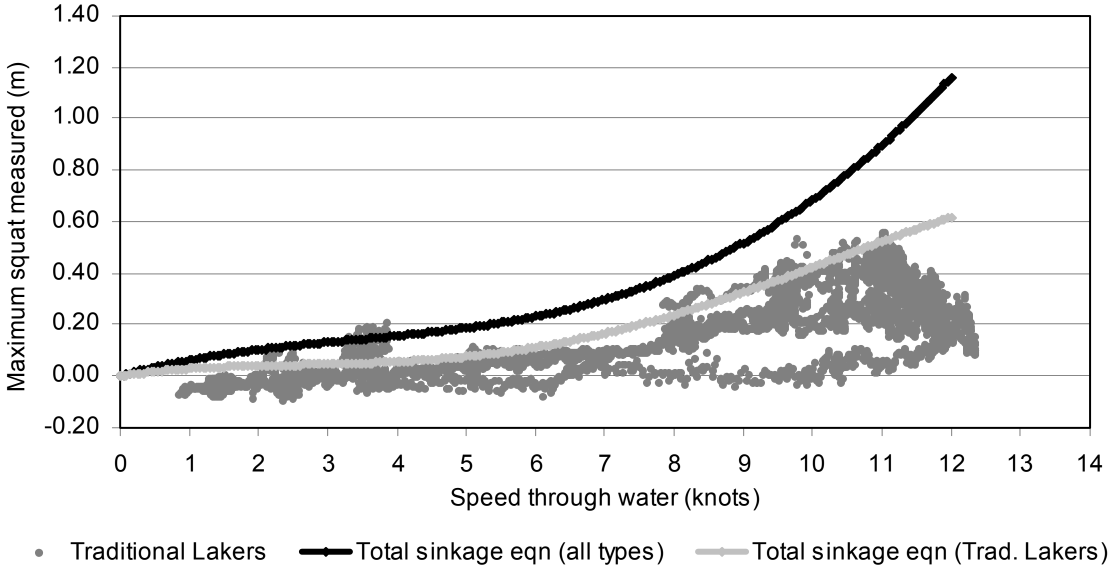

Figure 22 Dynamic squat values with the equation for Traditional Lakers, Lake St. Louis.

2.9 Dynamic Squat Equation for Salty Laker Type (Lake St. Louis)

$$\text{Dynamic squat} = -0.000021 * V^4 + 0.0019346 * V^3 - 0.0204885 * V^2 + 0.0797849 * V \quad (2.9)$$

This equation is valid for speeds from 0 to 12 kn. The dynamic squat values obtained with the equation for Salty Lakers are illustrated in Figure 23.

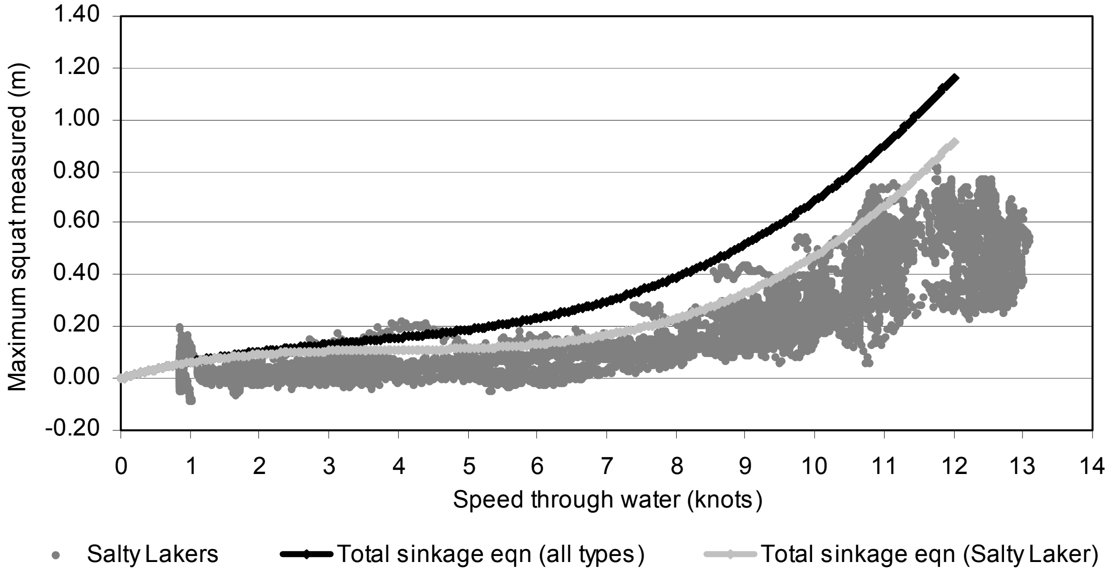

Figure 23 Dynamic squat values with the equation for Salty Lakers, Lake St. Louis.

2.10 Dynamic Squat: Conclusion

In this section, equations describing dynamic squat of ships as a function of speed-through-water were presented. One equation to suit all types was presented for South Shore Canal, and another one for Lake St. Louis. Other equations that suit specific ship types were also presented for South Shore Canal and for Lake St. Louis. All these curves provide realistic and safe estimates of dynamic squat behaviour including squat effects as well as most other additional effects such as water surges.

3. UNDER-KEEL CLEARANCE

The two main objectives of this section are as follows:

1) Identify all the critical sections of the Seaway where negative UKC values were found.
2) Verify whether critical computed UKC values are real and have a real physical significance.

3.1 Locating Negative UKC Values

Computed UKC results by F-W-G were carefully analysed for all ships. It was found that UKC values smaller or equal to zero occurred at 116 locations along the seaway. Twenty-four of those were located at the entrance of Beauharnois lock, with UKC values smaller (i.e. more critical) than -2 m and UKC amplitude variations of up to 3.5 m for two specific ships (*Lake Carling* and *Mariupol*). Values at those areas were considered potentially anomalous and needed to be confirmed, especially at Beauharnois' lock entrance where UKC values were found to be most critical. The table in Appendix I shows identified anomalous UKC locations along with UKC values and channel bottom elevations used for computation. Table 4 shows the number of anomalous UKC values identified in the St. Lawrence Seaway in all critical sections between St. Lambert and Beauharnois locks as a function of distance from a known position originating at 3.3 km upstream from the Laurier dock located in the Port of Montreal. Note that the corresponding distances from the Laurier dock to St. Lambert and Beauharnois locks are 2.4 km and 47.2 km respectively.

Table 4 Number of anomalous UKC values identified in St. Lawrence Seaway between St. Lambert and Beauharnois locks – extracted from F-W-G data

Distance – Channel station at midship (km):	0 to 5	5 to 10	10 to 15	15 to 20	20 to 25	25 to 30	45 to 50
Number of ships where UKC is negative or equal to zero:	4	2	2	8	6	3	9
Number of locations where UKC is negative or equal to zero:	8	16	4	29	15	15	29
Number of locations where UKC is smaller than - 0.5 m:	0	1	0	1	2	0	24
Total number of locations where UKC is negative or equal to zero:	116						

Note: Origin of distance is at 3.3 km from the Laurier dock in Port of Montreal

F-W-G's UKC values were computed by subtracting the maximum channel bottom elevation (extracted amidships between –10 m port and +10 m starboard positions) from the ship's minimum keel elevation (MKE).

MKEs were determined by computing the sinkage at the centre of the ship, adjusting to the lowest point at the bow or stern according to the trim, and then adjusting to one half the beam according to the roll or heel. It was assumed that a ship is a rigid body and that it does not twist or bend significantly. Thus, the lowest elevation at the corners of the ship block defined by the ship beam and length was determined. It was considered that this could be used with highest channel bottom elevation at the midship because the lowest point of the ship would eventually have to cross that channel cross section. This allows a bit of conservatism in the UKC since the bottom elevation could be slightly lower on the side of the MKE.

It was considered that, because ships tend to follow the same path in the channel, searching for the maximum channel bottom elevation directly under the ship would provide the most likely minimum UKC. Maximum channel bottom elevations were interpolated from the latest vertical data referenced to IGLD85 datum. Table 5 shows the number of anomalous UKC locations found as a function of position from amidships.

Table 5 Number of anomalous UKC locations as a function of position from amidships extracted from F-W-G data

Position from amidships (m)	-10	-5	0	5	10
Downbound ships	1	1	1	0	4
Upbound ships	65	12	5	7	20
Total number of anomalous UKC locations:				116	

Note: Negative position indicates port side, positive indicates starboard.

3.2 Reliability of UKC Values – Do They Have Physical Significance?

Anomalous UKC values could be explained by excessive squat (e.g. ship meeting situations, in theory enabling higher squat values); errors in GPS elevation data, keel elevations, and channel bottom elevations; or numerical errors. Note that errors are cumulative in the computation of UKC values.

Ship-Meeting Situations

Ship-meeting situations were analysed using 53 ship-meeting situations that were recorded during the data collection period between October 24 and November 14, 2000. All ship meetings were checked and compared with each vessel's positions and periods of time where UKC anomalies were identified. It was found that none of the recorded ship meetings corresponded to anomalous negative UKC locations or recorded time and it is therefore considered that, within the scope of this project, ship-meeting situations cannot explain UKC anomalies. Available ship meetings either happened before or after the moment when GPS instruments on vessels are known to have recorded data related to negative UKC results.

GPS Elevation

GPS elevations were previously validated within this project's framework and the accuracy of collected data was estimated to 10 cm 95 percent of the time. This means that 5 percent of the time, errors in GPS elevation may be larger and this may partially explain some anomalous UKC values. This accuracy not only takes into account the errors inherent in GPS positioning, but also the distance between the ship and the base station – i.e. the accuracy decreases as the distance increases – and the additional errors resulting from the strong geomagnetic activity that was occurring when GPS data were collected. The problem is that not all variables are currently available to us and there is therefore no way to verify the exact accuracy of GPS elevations without first accessing the complete set of used variables (such as variance and covariance matrices) for GPS data computation and processing. Moreover, some small errors (up to 5 cm) can be introduced when the ellipsoidal elevation given by the GPS data processing is transformed to an IGLD85 elevation. Therefore, it can be stated that GPS imprecision could partly explain some anomalous UKC values as well as some high UKC amplitude variations at Beauharnois lock. For that specific site, the structure of the lock can hide some satellites and the proximity of the walls is favourable to produce multipath errors, both being elements that reduce the accuracy.

However, GPS elevations were further individually plotted and analysed for each of the 116 anomalous locations and none showed clear visible erroneous behaviour. Nevertheless, this does not discard possible errors present on a larger scale within the signal. Some “jumps” in GPS elevation of up to 20 cm were indeed observed within global data, but not close to computed negative UKC locations. Figure 24 shows such jumps found very near Mercier bridge at station 23200 for the transit of the ship *Lake Carling*. Note that in this case, GPS data has already been cleaned by F-W-G during their UKC computation. Another example of an apparent anomalous jump (18 cm in just 2 seconds) is shown in Figure 25 for the ship *Mariupol* at station 22918, some 350 m downstream of Mercier bridge. This last jump is, however, observed not to be located close to a critical UKC location. These jumps, if they are not revealing a real vertical movement of the ship, can be the result of a satellite leaving or entering the process and affecting the solution. The impact of such apparent jumps in observed GPS data is not easy to assess, but this would affect keel elevation calculations and could then partly explain calculated negative UKC values.

Keel Elevation

As previously mentioned, MKEs were computed by F-W-G, first computing the sinkage at the midship keel, adjusting to the lowest point at the bow or stern according to the trim, and then adjusting to one half the beam according to the roll or heel. Sinkage at midship mainly relies on GPS elevations and ship geometry. Therefore, the ship geometry that was used for the computation of keel elevations is another variable that was checked, since the vertical position of GPS antennae and its relation to ship geometry enables the calculation of the ship’s keel elevation. The geometry of vessels showing the worst UKC values where checked, but no significant errors were found.

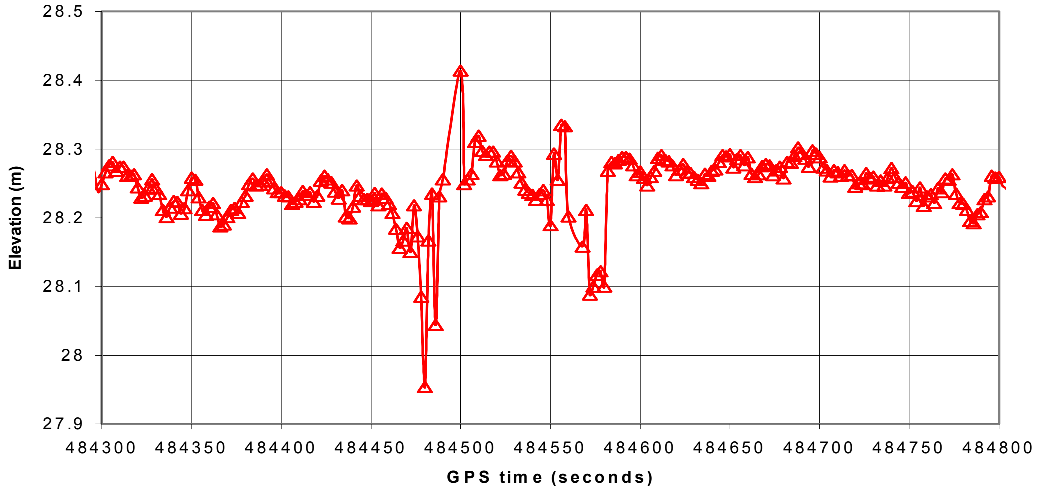

Figure 24 Anomalous GPS elevation behaviour for *Lake Carling* near Mercier Bridge at station 23200.

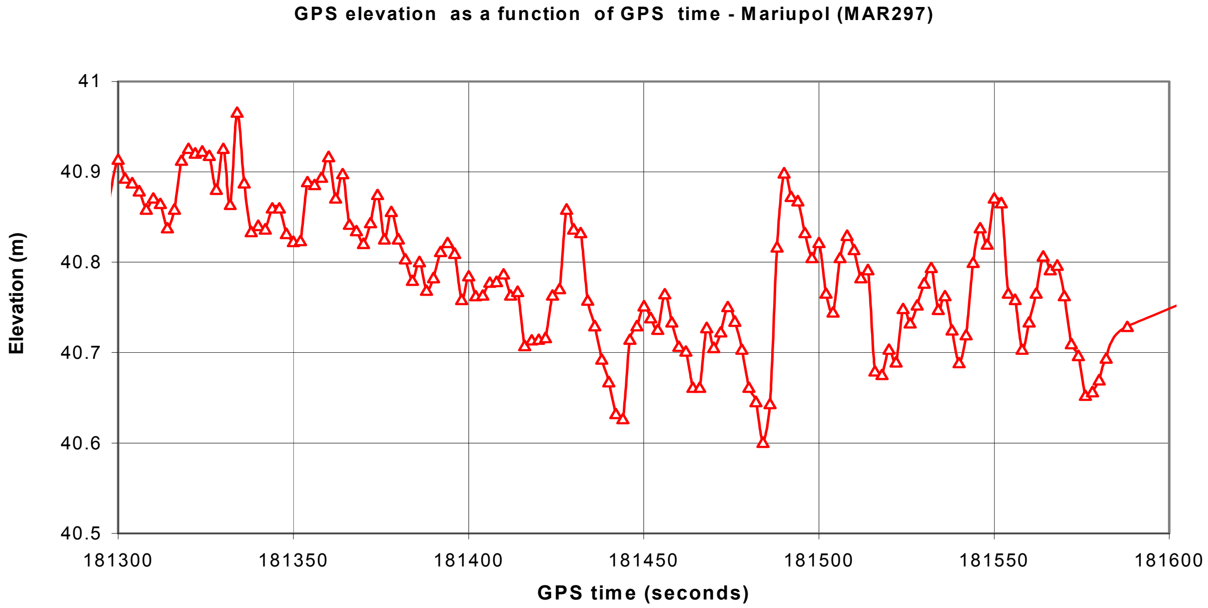

Figure 25 Apparent jump in GPS elevation for *Mariupol* at station 22918, some 350 m downstream of Mercier Bridge.

Channel Bottom Elevations

Maximum bottom elevations were analysed for all 116 anomalous locations. Since bottom depths recorded during bathymetric surveys and used in this study were measured with the water level as a reference, accuracy of the former is directly proportional to the accuracy of the latter. One is therefore forced to consider water level precision.

Water Level Precision

At this point, accuracy of the water elevations used is not exactly known and it is mainly acknowledged that it is inversely proportional to the distance from the water level stations that record it. The precision is actually estimated by the Seaway to be ±5 cm near stations and can decrease to at least ±10 cm in between stations. One such station is installed at Beauharnois lock and water elevation errors can therefore not explain negative UKC values of several metres at this location. Few critical UKC data near other water level stations are currently available.

It is noteworthy to mention that a visit of the Seaway's infrastructures was made on November 22, 2001. Three items were found on this occasion:

1) The water level measured at St. Lambert lock was around 10 cm higher than the water level measured at Cote St. Catherine, something theoretically impossible to observe in nature that is equivalent to water running in an upstream direction. This was also in direct contradiction with measured GPS elevations indicating that the water level at St. Lambert lock was nearly 10 cm lower than the water level measured at Cote St. Catherine. This adds up to some 20 cm difference of elevation between those two stations.
2) Measured GPS elevations indicated that the ship used during bathymetric surveys was shown to have a squat of some 9 cm at a speed of 8 kn. This has a direct impact on the precision of previously surveyed bottom depths. Until now, this effect had not been taken into account by the survey team of the Seaway.
3) There seems to be no one person formally in charge of water level gauges and maintenance is not systematic.

These three observations suggest that water level measurement accuracy is not optimal. This directly affects the precision of available surveyed water depths and consequently bottom elevations, since water levels are used as a reference during sounding. It is also known that other factors affecting the precision of surveyed water depth, such as the speed of sound in water as a function of water temperature, were only recently completely tuned and integrated in the methodology used by the Seaway during hydrographic surveys.

UKC Locations Match High Bottom Elevations Extracted by F-W-G

Graphical plotting of bottom elevations used for UKC calculations by F-W-G showed that all 116 anomalous UKC locations corresponded exactly to high bottom elevations found in files used for UKC computation, sometimes shown as spikes in bottom configuration. Moreover, it was found that high bottom elevation amplitude matched high UKC amplitude at the Beauharnois lock entrance (channel stations between 47.0 km and 47.4 km).

Verification of Bottom Elevation Extraction

Several anomalous locations were verified to determine whether channel bottom elevations were extracted correctly (we did not check the algorithm used by F-W-G to extract or interpolate bottom elevation). Many matched available files of bottom elevation data, which are presumed to have been used for UKC computation. It turned out, however, that some high bottom elevations of some critical locations could not be found near the expected coordinates of anomalous locations, even if such high elevations could be found located farther away within the same file. This is especially true for most critical locations situated near Beauharnois lock, where the worst UKC values have been found. It therefore seems that some errors were made during the channel bottom extraction procedure. More details on this topic are presented in section 3.5.

Can High Bottom Elevations Be Explained by a Coordinate Shift?

It was suggested that negative UKC values could be explained by a coordinate shift that occurred while using a specific bathymetry file (note that some 52 different bathymetric files were provided by F-W-G). For some critical areas, such a shift could then have an impact on extracted bottom elevation values.

A coordinate shift could be explained by:

- The fact that bathymetric data provided by the Seaway to F-W-G was originally partially expressed in UTM or MTM coordinates, some in NAD83 datum and some others in NAD27 datum, depending on the location and date of the surveyed area of the Seaway;
- The fact that, previous to UKC and squat calculation, F-W-G converted all data to a common UTM NAD83/IGLD85 coordinate system and some errors could have occurred at this point.

This idea was supported by the fact that some GPS positions of the ship *Lake Carling* (LAC315) were plotted and it was found that directly downstream of Beauharnois lock, the ship is very close to the approaching wall of this lock. That section of the Seaway was previously identified as being very critical and showed many negative UKC values. It was first suggested by the Seaway that the ship did not really approach the wall; it was instead speculated that an error occurred in the manipulation of various hydrographic files. The error would be to use UTM NAD83 for the ship transit coordinates, along with UTM NAD27 coordinates for the bathymetric data. This error would explain an apparent shift of some 25 m to the east (i.e. toward the approaching wall).

Such a shift was, however, very improbable and a simpler explanation has been found. The transit position of the ship was plotted and is shown in Figure 26. It clearly shows the ship's direction changing toward the lock's approaching wall. The transit position of that ship has also been plotted over the latest bathymetric data in the area and both

a) the ship's position matches the centre of the Seaway canal and
b) the bottom elevation peaks extracted by F-W-G match the hydrographic data.

The ship *Rt. Hon. Paul Martin*, showing several negative UKC values near Beauharnois lock, was also analysed. The transit position of this ship was plotted and is shown in Figure 26. It clearly shows the ship's direction changing toward the lock's approaching wall. This position was compared to an available video session in which it was possible to see that the ship actually touches the approaching wall at the time corresponding to the GPS position close to the wall. It was not possible, however, to see whether the midship section gets close to the wall. Although the ship appears to be parallel to the wall on the ECDIS (Electronic Chart Display and Information System) screen, this does not guarantee that it is the case, because this information varies in accordance with the system used on board. Some systems are directly connected to the gyro, giving a true projection, while others project the ship's direction by GPS interpolation and are less accurate at low speed.

In total, three ships show several negative UKC locations directly downstream of the Beauharnois lock area (*Lake Carling*, *Rt. Hon. Paul Martin* and *Mariupol*). The plotted trajectory of these three ships clearly indicates that they have very closely approached and probably even touched the approaching wall of the lock (see Figure 26). Moreover, the latest available bathymetric data corresponding to the edges of the approaching wall show a dramatic decrease of depth, indicating that this proximity to the wall creates a more critical condition in terms of UKC values. This last critical condition therefore partly explains why those three ships show negative UKC results.

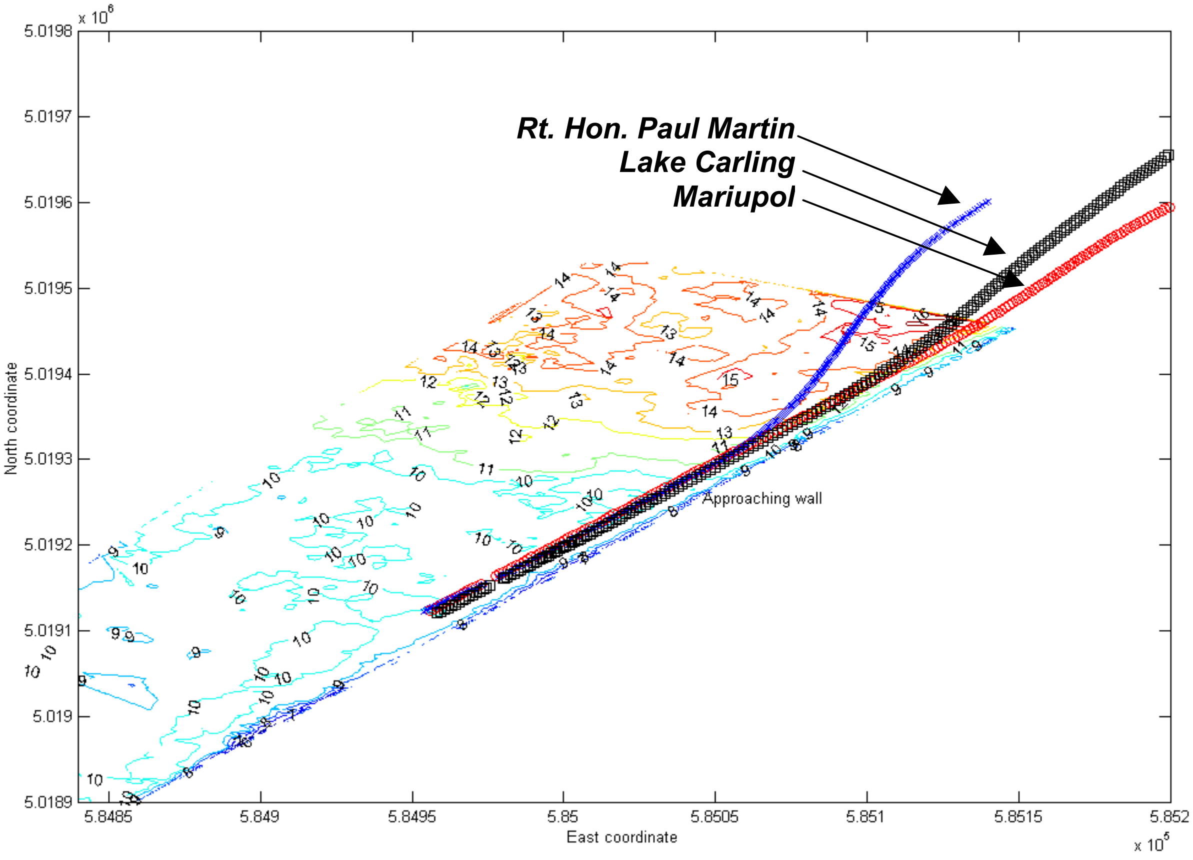

Figure 26 Transit trajectories for ships showing negative UKC values near Beauharnois lock.

3.3 UKC Computation of a Complete Ship Transit

To further validate the accuracy of negative UKC results provided by F-W-G, it was decided to recalculate a complete ship transit between St. Lambert and Beauharnois locks. The maximum channel bottom elevations were recalculated using a total of 33 bathymetric files provided by F-W-G. The Seaway had originally provided those files.

Some of the original bathymetric files contained UTM (Universal Transverse Mercator) and some others contained MTM (Modified Transverse Mercator) coordinates, depending on the years in which they were surveyed. The hydrographic surveys were performed during several years; the most recent ones available to us were done during the year 2000. Because of this, and for simplification purposes, F-W-G transformed all available bathymetric data to UTM NAD83/IGLD85 coordinates and the original files with the original format provided by the Seaway are not available.

All bathymetric files also corresponded to one or more of the 1 km-long survey areas that were delimited by the Seaway. Before 1999, all those areas had different names and the system used to manage them was complex. For this reason, the Seaway has recently greatly simplified the designation of those names and this enables a more efficient classification and archiving of all data related to those hydrographic areas. For example, numbers between 100 and 200 now designate all hydrographic areas located between St. Lambert and Cote St. Catherine locks, while numbers between 200 and 300 designate all areas located between Cote St. Catherine and Beauharnois locks. Moreover, because of the inherent complexity of the classification system previously employed by the Seaway, F-W-G completely renamed all bathymetric files. Therefore, not only the names, but also the format of the original hydrographic files have been changed.

To further complicate things, all bathymetric areas are also characterized by a reference water elevation noted at survey time. The bottom elevation can only be calculated by knowing this reference water level. Because some hydrographic areas have been surveyed many times, many of the hydrographic areas correspond to one or several of the bathymetric files available to us, as well as to one or several reference water elevations, simply because the water level constantly fluctuates. It has therefore been a complex task to create order with all of the hydrographic files, particularly because some detective work was necessary to link all bathymetric files with a correct water reference level. This has been done, to some extent, with incomplete information originating both from the Seaway and from F-W-G.

A New Bottom Elevation Processing Is Used

The ULaval results are computed using a new bottom elevation processing. This ULaval bottom processing searches for the highest bottom elevation found under the ship at midship. The searched area corresponds to a rectangle 10 m long (5 m before and 5 m after the midship cross section) and 20 m wide (10 m port and 10 m starboard). This area is therefore very similar to the 20 m (10 m port and 10 m starboard) midship cross section used by F-W-G to calculate the maximum bottom elevation under the transiting ship.

Note that during this process, the bathymetric data and reference water levels have only been thoroughly validated by the Seaway for the area near Beauharnois lock. To this end, the Seaway provided the latest year 2000 bathymetric data and the corresponding reference water level. Data for areas located elsewhere along the Seaway have only been used in accordance with the correspondences that were established between all available bathymetric files (originally provided by the Seaway, but transformed by F-W-G), reference water levels and hydrographic areas defined by the Seaway.

Comparison of UKC Values Computed by F-W-G and ULaval near Beauharnois Lock

Figure 27 shows a comparison of UKC values computed by F-W-G and ULaval for the transit of the ship *Lake Carling*. Among the 33 instrumented ships, *Lake Carling* is the most critical in terms of UKC values and is characterized by the highest number of identified negative UKC values. This is especially true for the area directly downstream of Beauharnois lock. Results are therefore shown for that most critical area (between stations 47000 and 47500).

Figure 27 indicates that for this area, the ULaval UKC values are less critical as compared with F-W-G results. ULaval results show only a few negative values of – 0.01 m near station 47300, while F-W-G results show many negative results in that section. Such differences are partly because of the new year 2000 bathymetric data used, known to be more precise. However, differences are mostly a direct result of the ULaval bottom processing. Note that ULaval has only used the latest year 2000 bathymetric data for this area near Beauharnois lock. These data were provided directly by the Seaway and were not available to F-W-G.

UKC results computed by ULaval, using bathymetric data surveyed in 1999, are shown in Figure 28. Note that negative UKC values of –1.29 m near station 47400 appearing with the year 1999 data disappear when the year 2000 data is used. This is only because of the higher reliability of year 2000 data. This indicates that older hydrographic files are not as precise as more recent ones.

It therefore seems that, at least for this area, some errors were made by F-W-G during bottom extraction procedure. This explains the sharp bottom variations that appear in F-W-G results, variations that do not exist in reality (see Figure 26 for bathymetry near Beauharnois lock). Contrary to F-W-G calculations, the ULaval results are in agreement with the latest available hydrographic data and gentler bottom variations are found.

UKC Values Computed by F-W-G and ULaval: South Shore Canal

Figures 29 and 30 show a comparison of UKC results by F-W-G and ULaval for the section delimited by St. Lambert lock and Lake St. Louis (between stations 3000 and 26000). UKC values have been computed for the transit trajectory of the ship *Lake Carling*.

Results indicate that globally speaking, UKC values calculated by F-W-G are similar to the ULaval calculations. Results are most similar between stations 18450 and 26000 but show some differences between stations 3000 and 10300. Similar differences can also be seen between stations 17890 and 18450.

Note that both F-W-G and ULaval results show negative UKC values. However, ULaval results are often slightly smaller (i.e. more critical). Those differences could easily be explained by using slightly lower reference water levels during computation.

Most critical UKC values are a result of the bathymetry used. For example, negative UKC values found at stations 24869 (UKC = –1.29 m) and 18782 (UKC = –1.19 m) are directly related to high spots found in bathymetric files Xbe16a3s and Xbd1483S, respectively. Figures

31 and 32 graphically show the bathymetric data found in those files. The identified high spots that explain the computed negative UKC values are shown (depths of 8.16 m and 7.83 m for stations 24869 and 18782, respectively).

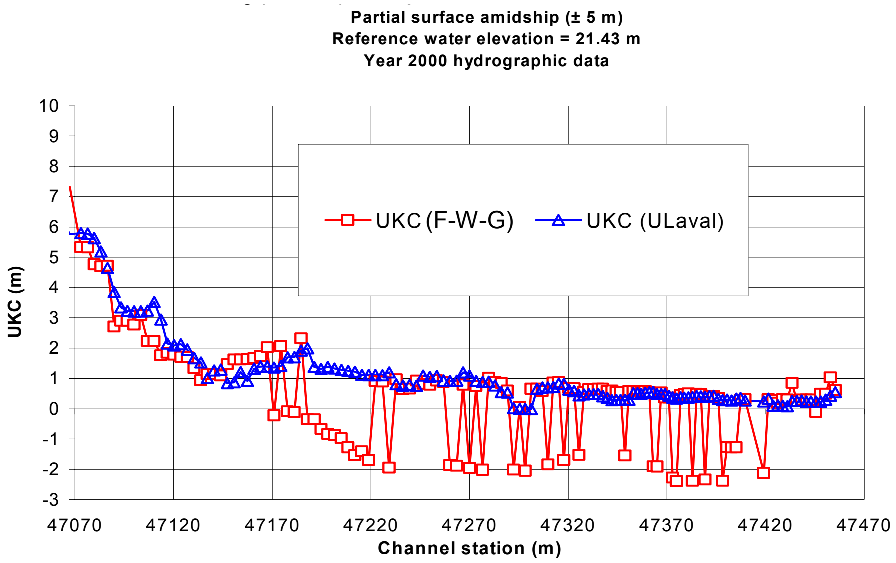

Figure 27 Comparison of UKC values, *Lake Carling,* near Beauharnois lock – Year 2000 bathymetric data.

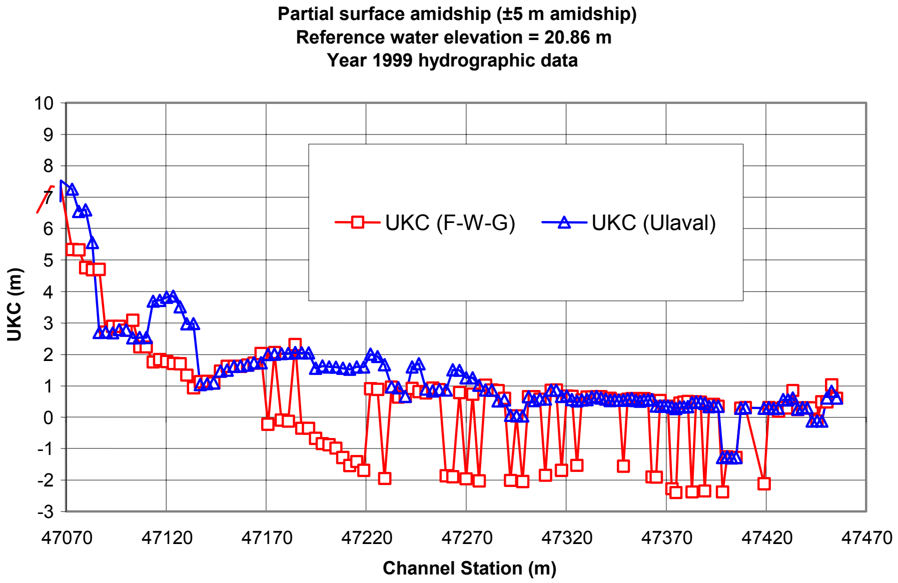

Figure 28 Comparison of UKC values, *Lake Carling,* near Beauharnois lock – Year 1999 bathymetric data.

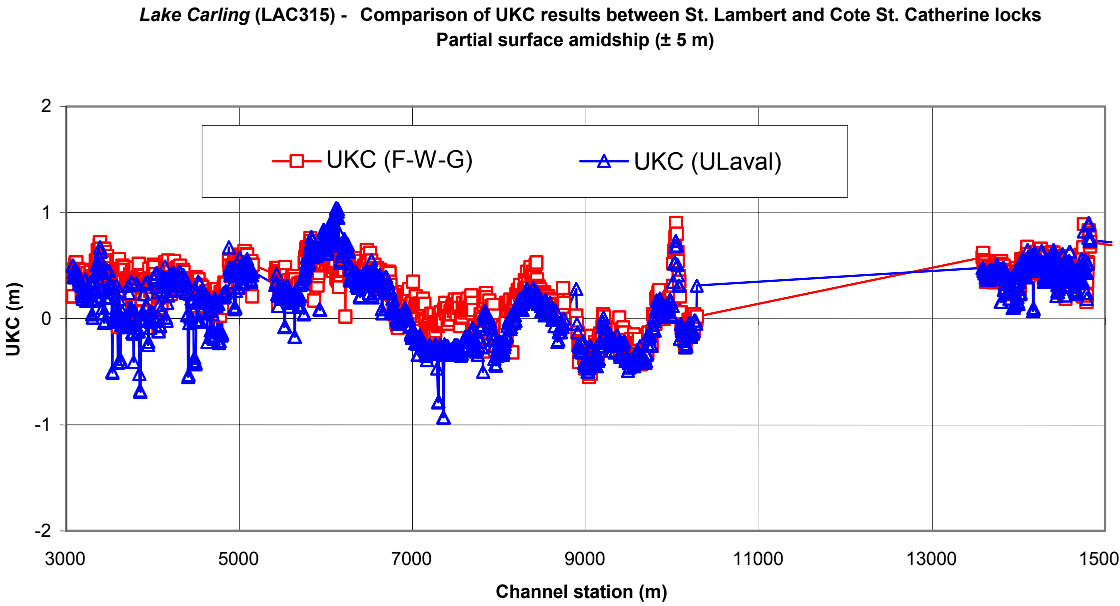

Figure 29 ULaval and F-W-G *Lake Carling* UKC values between St. Lambert and Cote St. Catherine locks.

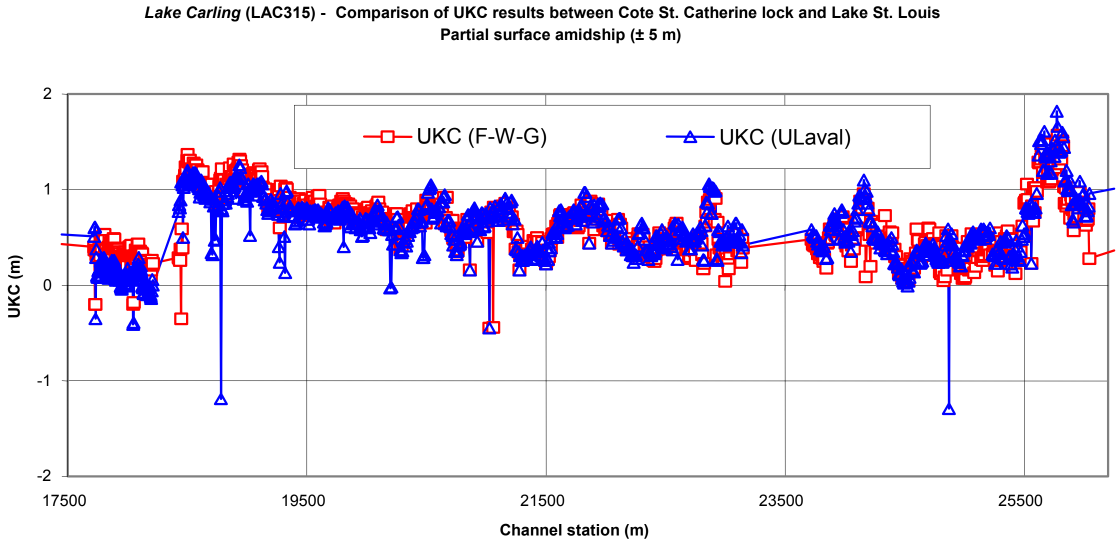

Figure 30 ULaval and F-W-G *Lake Carling* UKC values between Cote St. Catherine lock and Lake St. Louis.

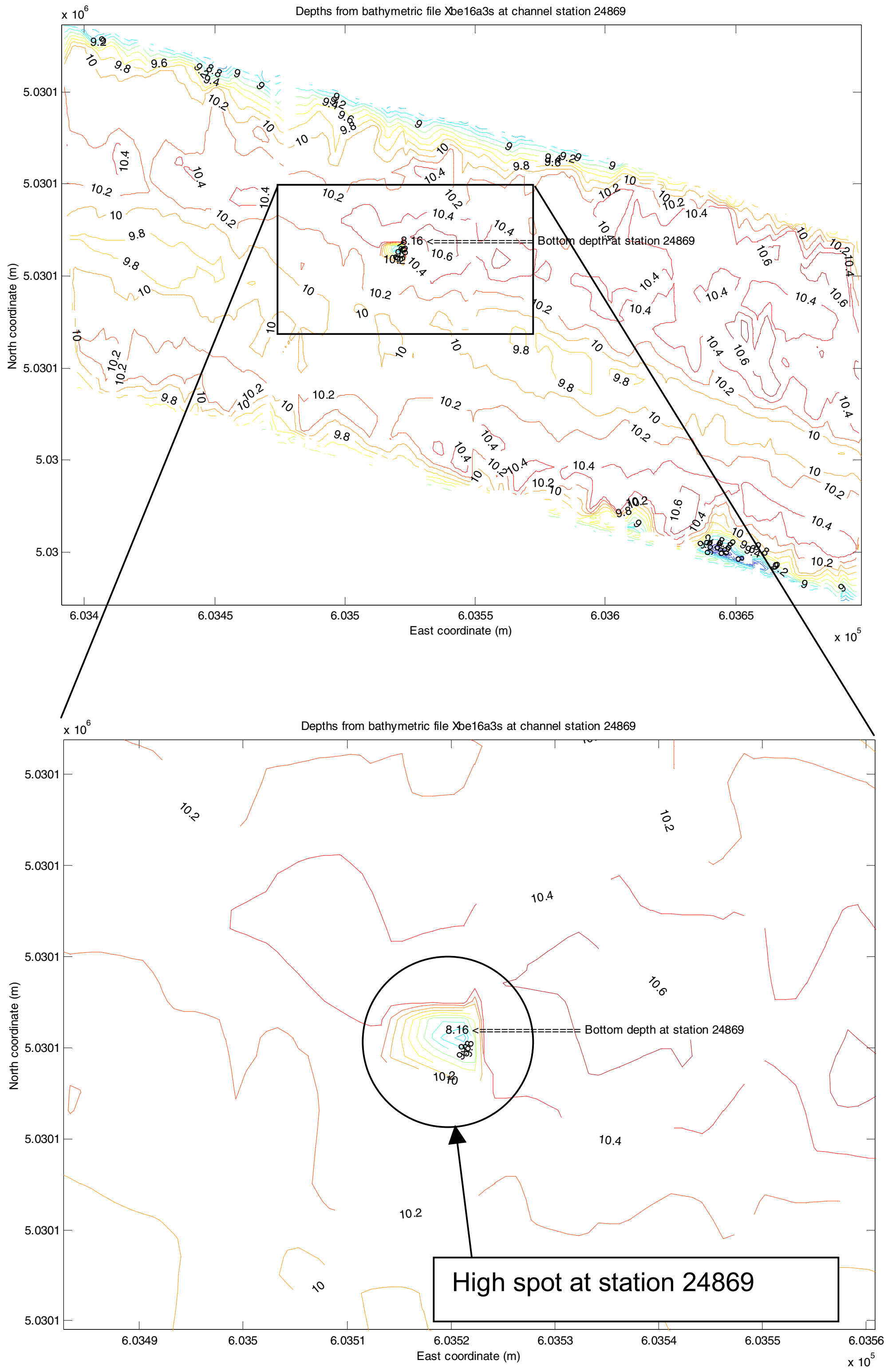

Figure 31 Bathymetry of high spot at station 24869 (where UKC = –1.29 m)

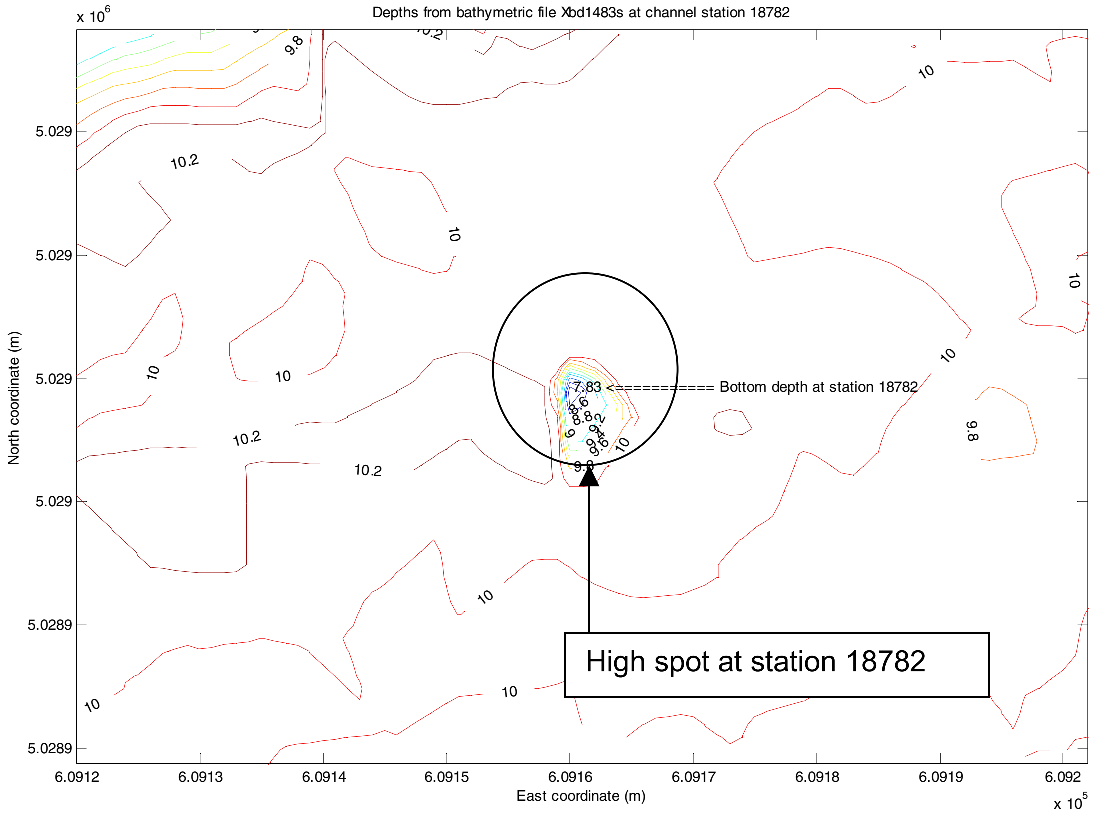

Figure 32 Bathymetry of high spot at station 19782 (where UKC = –1.19 m).

3.4 Under-Keel Clearance: Conclusions

The task to precisely assess UKC values is more complex than originally thought. As expected, not all negative UKC values are as critical as first indicated. This can at least be stated for the area directly downstream of Beauharnois lock. Because of the many limitations on the accuracy (e.g. GPS precision but mainly bathymetric data precision), and because those limitations have a direct impact on the precision of computed UKC values:

- We are forced to conclude that negative UKC values determined by F-W-G are probably all fictitious (i.e. they do not accurately reflect reality). However, instrumented ships may well have touched bottom at some points during their transit.
- Although imprecision in GPS and water level data of 10 and 30 cm, respectively, may lead to slightly higher/lower estimations of UKC, they cannot account for the large calculated negative values.

- Most calculated negative UKC values originate from the available bathymetric data that are not sufficiently reliable. However, some negative UKC values originate from a numerical problem in F-W-G's algorithm. This is particularly true for negative UKC values calculated along the downstream approach wall of the Beauharnois lock.
- The limited accuracy of the bathymetric data is partly the result of the cleaning procedures currently applied by the Seaway on their bathymetric files. These data reduction processes do not follow a formalized and validated procedure such as ISO14000.

3.5 Under-Keel Clearance: Recommendations

To obtain the correct UKC values in the St. Lawrence Seaway, the following actions are required:

1) During bathymetry soundings, validated local water levels must be obtained.
2) Adequate accounting must be made of the sounding vessel's (*Maisonneuve*'s) squat.
3) Sounding instruments must be calibrated and validated. (The calibration is usually done but validation procedures are not carried out.)
4) The DGPS (Differential Global Positioning System) used for sounding must be installed and used correctly.
5) Data reduction processes aboard and in the office must follow a formalized and validated procedure. File cleaning procedures must be systematic and complete.
6) Bathymetric sounding must be reduced to and referred to a fixed (IGLD85) vertical datum that is independent of water fluctuations.
7) All potentially critical high spots must be re-sounded until their real elevation is known with certainty.
8) All bathymetric survey files representing the most recent information of each kilometre of the Seaway must be referred to a unique positioning system (MTM for XY and IGLD85 for Z) in a unique password-protected file directory. These files should be classified according to the new Seaway designation system (100, 200, etc.). Each file must contain the date of the survey and an indicator of level of confidence (or precision).
9) Once this bathymetric data is validated and accessible, the ULaval UKC algorithm (or another) can be used to calculate UKC values of various ships. The resulting picture will then be within the bathymetric sounding and ship GPS-OTF (GPS on-the-fly) accuracy.
10) The ULaval algorithm could also be used to identify the high spots for each kilometre for various water levels (particularly the alert level).

All these steps are required to obtain the true UKC picture. Until such time, UKC estimates by F-W-G or those reported by ULaval are unreliable and do not adequately reflect the reality of the Seaway.

4. STRENGTHENING THE WATER LEVEL NETWORK AND BATHYMETRIC SURVEYS

This section contains some reflections on ways to enhance the Seaway's water level network and bathymetric surveys. After presenting the status quo, we present the objective, the required resources, management alternatives and our conclusions.

4.1 Management Options for Strengthening the Water Level Network

Status Quo

Currently, there are enough water level recording stations, enough knowledge of the system by the operators and enough real-time links to enable the Seaway to have a good picture of water depths along the navigation route. This information enables the Seaway to set the permissible draft and to locate the critical shoal areas. At the same time, despite the recent investment in a new site and ad hoc system improvements, it seems that the water level network is currently (a) not recognized as an entity, and (b) not any one single person's responsibility, nor are there formally assigned technical resources to support it.

Objectives

There is a desire among Seaway management and employees to have a better system. There are essentially two end users: operators/managers and the bathymetric survey team. Operators/managers require better information to optimize permissible draft and facilitate water management decisions. Hydrographers require better information to increase the precision of their bathymetric surveys. A better system would mean easier access, more stations, more homogeneous technology and more reliable information. It would also require that the system officially be someone's responsibility.

Criteria

A good water level network requires:

- a common and easily understood reference datum and its link to another commonly accepted datum, e.g. NAD83;
- units of measurement (e.g. imperial or metric) that are comprehensible to users;
- dependable gauges;
- calibrated gauges that are verified on a scheduled basis;
- sufficient sampling frequency to record and reveal all significant water level fluctuations;
- a reliable telemetry system that gets the data from the stations to the users (Seaway operators, shippers, masters or bathymetric surveyors);
- data presented in an easy-to-understand language and format;
- coverage that meets operational needs.

Requirements and Resources

To a certain extent, the Seaway's system does meet most of these objectives. However, a formal project is required to upgrade the system to fully meet all criteria. Meeting these objectives is not as simple as it may first appear:

- The choice of a reference datum requires a specialist in geomatics who understands the Seaway's history and operational needs.
- The units of measurement do occasionally lead to misinterpretations and it is therefore probably advisable to use both units.
- Dependable gauges probably mean gauges whose technology is neither too old nor too new.
- Calibrated gauges require a responsible technician who is fully qualified and autonomous and is fully conversant with each gauge (noting that the types of gauges used in the network vary from one site to the next). The technician must also look after people living near the gauges who are willing to take local manual daily readings (to validate automated information).
- Most gauges filter out high-frequency water level fluctuations. In most cases this is desirable but they must somehow show the magnitude of negative water surges that could threaten a vessel's under-keel clearance.
- A reliable telemetry system implies redundancy, validation process, power failure management, real-time transmission and careful consideration for the locations of end users (e.g. on board a ship). It requires that qualified electronic technicians and engineers be assigned the responsibility to build, upgrade and maintain the system.
- End users are very particular when it comes to data presentation. Getting the water level information presented in the correct language and format to each user requires a concerted effort and some trial and error.
- The stations must cover key (critical) water level locations. Elsewhere, it has been found very useful to merge a hydrodynamic computer model of the water drainage network since the model can assist in interpolating between stations and can reveal if a particular gauge's reading is inconsistent with readings at other stations. The design of the water level system and the integration of a numerical model require someone qualified in water resource simulation.

Alternatives

There are three alternatives open to the Seaway:

1) Status quo: Currently, the system seems to be sufficient to provide a picture of available depths. However, it is insufficient to enable ship under keel-clearance optimization and precise bathymetric surveys.

2) Internally building and supporting a water level network: The Seaway could launch a "water level network project" whose objective would be to design, build and maintain a system responsive to corporate objectives that meets the criteria and requirements of such a system. This approach would require a very capable project leader backed by management and well supported on the technical and financial sides. The capital side of the project would probably extend over a couple of years. At the same time, internal

human and financial resource reallocations would be required to sustain the system. This solution may seem to save the Seaway money, but because this is not the Seaway's area of expertise, it may be an exercise in frustration.

3) Outsource: A capital project could be awarded to a company to design, upgrade and maintain the network (for a period of 2 years). This could be followed by a multi-annual service contract to sustain the system. The advantages (at least theoretically) of this alternative are that the project will get done by a team having the managerial, human, technical and financial means. However, the choice of technology is critical. In some instances, other water level networks have been very expensive to install. There is also the long-term risk that the Seaway will lose its remaining internal expertise.

Conclusion

To a certain extent, the question is whether the Seaway is willing to invest in and support its internal human resources or whether it considers that the water level network is not a part of its corporate service delivery and that, therefore, it would be advisable to hand the water level network over to a third party.

4.2 Regarding Bathymetric Soundings

Following are some of the most important issues facing management.

Status Quo

Traditionally, the Seaway detected shoals by trolling a bar attached by chains at the waterway design depth. This required a large team of people to handle the equipment, keep the boat "on line" and observe water levels. This method did not measure the seaway's depths, it only showed whether there was an obstacle popping up above grade. It was a physically based system – when the bar hit something, you knew it for sure.

Over the past few years, the technology has changed from 19th to 21st century. There is now:

- a new sounding vessel (a catamaran formerly belonging the the Canadian Coast Guard as *GC-06* is now renamed *La Maisonneuve)*
- a new captain (formerly a crane operator)
- a new (in-house) ship positioning system (DGPS)
- new technicians (formerly working in non-technical posts)
- a new project leader (formerly a barge operator)
- a new technical advisor and quality control agent (with an electrical engineering background)
- new bathymetric instruments (sweep transducer, gyroscopes, motion detectors)
- new data acquisition software (known as HYPACK)
- new data treatment and cleaning approaches

- new file archiving systems
- new data mapping formats
- most importantly, a new mandate (stemming from new economic pressures and safety concerns) that insists on very accurate and precise bottom bathymetry of extended areas.

All of Seaway's personnel have responded remarkably well to this new mandate and technological challenge. Each year has seen a dramatic improvement in data quality and information packaging.

Objective

There is a great need (from a safety point of view) and a great desire (from an economic point of view) to go to the next level: get more precise, up-to-date and reliable data covering a larger territory.

Criteria

The goal is total coverage with 10 cm accuracy in shallow portions of the waterway.

Requirements

Bathymetric sounding is now very sophisticated and requires the mastery of high-tech instruments, software and procedures. It also requires systematic approaches, from data acquisition, to near-real-time data validation, to quality control and data presentation, in a homogeneous and comprehensible geographic reference system. To be useful, a lot of territory must be reliably covered on short notice. B. Morse performed time management studies of bathymetric activities elsewhere that revealed that actual sounding time in a normal day was only about one hour. Time management methods are therefore essential. All this means that the technical team must be motivated, autonomous, capable and technically proficient. There must also be a commitment by management to provide adequate support and resources to do the job.

Alternatives

- Status quo: Under the leadership of Pierre Champagne, the bathymetry survey team has demonstrated how well it has advanced. However, without some changes, the full extent of the objectives cannot be achieved.

- Internal investment: The team could be boosted. Exterior consultants and/or resource people could be hired to work with the team to develop better methods, build up procedures and provide technical instruction. Team members could be sent on courses (DGPS, hydrography, computer skills and specific software applications (e.g. HYPACK)). The team could be given the required infrastructure support (data communication, validation, etc.). A technician with qualifications in modern hydrography could be hired. The advantage of this alternative is that it may save some costs, it keeps the activity under the direct control of Seaway management, it provides some jobs internally and it makes for a technically stronger Seaway. The disadvantages are that the objectives may never be achieved and the Seaway's under-keel clearance security may be threatened.

- Outsourcing: The other alternative is to give the mandate to a company that is in the hydrography business. This could be presented as a multi-year mandate since there would be some initial investments. The advantages of this approach are that (theoretically) the company would have the knowledge infrastructure and the human and financial resources and expertise to fully meet the objectives. In the long run it may even be less costly. The disadvantages are that the Seaway would lose direct control and some internal technical expertise, and some of Seaway personnel may have to change jobs.

Conclusion

Right now, the members of the technical team are doing their best, but to achieve the required precision to ensure safety and optimal under-keel clearance, they can no longer be left on their own. Management must intervene by providing technical and administrative leadership and additional resources to build a real dynamic sounding team or it must assess whether the job may best be done by an external firm that already has the managerial, technical and software infrastructure to support this very specialized and crucial mandate. Is the Seaway in the hydrography business and, if so, does it want to stay in this business? If yes, internal support is required; if no, outsourcing to a trustworthy company is required. If the outsourcing option is chosen, it may be combined with outsourcing the water level network since both operations have significant operational, knowledge and infrastructure overlap.

A STATISTICS FOR SOUTH SHORE CANAL

Summary (see section 1.2 of text for more details)

Values presented in tables of Appendices A, B, C, and D are the statistics of the five squat related elements ("raw", "area", "Tuck", "Barrass 2", "Simard") of each ship for each speed class (e.g. 0-5, 5-6, 6-7, 7+). The statistics are: average (avg), standard deviation (std) and sample size (nb). These statistics are used in the statistical tests on the average presented in Appendices E, F, G and H. The statistics were first computed in order to perform the tests to assess the repeatability between two sailings of the same ship (A.1 and B.1), then two ships of the same type (A.2 and B.2), and two ship types (A.3, B.3, C.1, D.1).

A.1 Statistics for ships passing twice

Algosar **day 303 (ALS303)**

	0 - 5	5 - 6	6 - 7	7 +
raw	avg = 0.15	avg = 0.34	avg = 0.44	avg = 0.43
	std = 0.05	std = 0.05	std = 0.09	std = 0.12
	nb = 319	nb = 281	nb = 1799	nb = 217
area	avg = 0.15	avg = 0.35	avg = 0.52	avg = 0.59
	std = 0.05	std = 0.04	std = 0.08	std = 0.17
	nb = 319	nb = 281	nb = 1799	nb = 217
Tuck	avg = -0.05	avg = -0.11	avg = -0.15	avg = -0.20
	std = 0.02	std = 0.04	std = 0.06	std = 0.13
	nb = 319	nb = 281	nb = 1799	nb = 217
Barrass 2	avg = -0.01	avg = -0.03	avg = -0.04	avg = -0.05
	std = 0.02	std = 0.03	std = 0.06	std = 0.13
	nb = 319	nb = 281	nb = 1799	nb = 217
Simard	avg = -0.01	avg = -0.01	avg = 0.01	avg = 0.01
	std = 0.02	std = 0.03	std = 0.06	std = 0.13
	nb = 319	nb = 281	nb = 1799	nb = 217

Algosar **day 316 (ALS316)**

	0 - 5	5 - 6	6 - 7	7 +
raw	avg = 0.15	avg = 0.25	avg = 0.32	avg = 0.35
	std = 0.06	std = 0.12	std = 0.09	std = 0.01
	nb = 413	nb = 771	nb = 1787	nb = 15
area	avg = 0.16	avg = 0.30	avg = 0.38	avg = 0.40
	std = 0.07	std = 0.10	std = 0.07	std = 0.01
	nb = 413	nb = 771	nb = 1787	nb = 15
Tuck	avg = -0.04	avg = -0.12	avg = -0.16	avg = -0.33
	std = 0.04	std = 0.07	std = 0.07	std = 0.05
	nb = 413	nb = 771	nb = 1787	nb = 15
Barrass 2	avg = -0.01	avg = -0.07	avg = -0.08	avg = -0.24
	std = 0.04	std = 0.06	std = 0.06	std = 0.04
	nb = 413	nb = 771	nb = 1787	nb = 15
Simard	avg = -0.00	avg = -0.04	avg = -0.04	avg = -0.19
	std = 0.03	std = 0.07	std = 0.06	std = 0.04
	nb = 413	nb = 771	nb = 1787	nb = 15

***CSL Niagara* day 315 (CNI315)**

	0 - 5	5 - 6	6 – 7	7 +
raw	avg = 0.14 std = 0.06 nb = 1294	avg = 0.30 std = 0.08 nb = 2154	avg = 0.00 std = 0.00 nb = 0	avg = 0.00 std = 0.00 nb = 0
area	avg = 0.16 std = 0.07 nb = 1294	avg = 0.33 std = 0.08 nb = 2154	avg = 0.00 std = 0.00 nb = 0	avg = 0.00 std = 0.00 nb = 0
Tuck	avg = -0.03 std = 0.04 nb = 1294	avg = -0.01 std = 0.07 nb = 2154	avg = 0.00 std = 0.00 nb = 0	avg = 0.00 std = 0.00 nb = 0
Barrass 2	avg = -0.09 std = 0.05 nb = 1294	avg = -0.13 std = 0.08 nb = 2154	avg = 0.00 std = 0.00 nb = 0	avg = 0.00 std = 0.00 nb = 0
Simard	avg = -0.03 std = 0.04 nb = 1294	avg = -0.03 std = 0.08 nb = 2154	avg = 0.00 std = 0.00 nb = 0	avg = 0.00 std = 0.00 nb = 0

***CSL Niagara* day 320 (CNI320)**

	0 - 5	5 - 6	6 - 7	7 +
raw	avg = 0.13 std = 0.10 nb = 1939	avg = 0.33 std = 0.07 nb = 2193	avg = 0.38 std = 0.08 nb = 435	avg = 0.00 std = 0.00 nb = 0
area	avg = 0.15 std = 0.12 nb = 1939	avg = 0.36 std = 0.07 nb = 2193	avg = 0.42 std = 0.11 nb = 435	avg = 0.00 std = 0.00 nb = 0
Tuck	avg = 0.01 std = 0.09 nb = 1939	avg = 0.02 std = 0.06 nb = 2193	avg = -0.01 std = 0.09 nb = 435	avg = 0.00 std = 0.00 nb = 0
Barrass 2	avg = -0.03 std = 0.11 nb = 1939	avg = -0.11 std = 0.09 nb = 2193	avg = -0.15 std = 0.10 nb = 435	avg = 0.00 std = 0.00 nb = 0
Simard	avg = 0.01 std = 0.10 nb = 1939	avg = 0.00 std = 0.08 nb = 2193	avg = -0.01 std = 0.10 nb = 435	avg = 0.00 std = 0.00 nb = 0

***John B. Aird* day 306 (JBA306)**

	0 - 5	5 - 6	6 - 7	7 +
raw	avg = 0.11 std = 0.06 nb = 1783	avg = 0.26 std = 0.06 nb = 1202	avg = 0.39 std = 0.08 nb = 871	avg = 0.34 std = 0.03 nb = 80
area	avg = 0.12 std = 0.06 nb = 1783	avg = 0.28 std = 0.07 nb = 1202	avg = 0.53 std = 0.11 nb = 871	avg = 0.45 std = 0.05 nb = 80
Tuck	avg = -0.01 std = 0.04 nb = 1783	avg = -0.02 std = 0.05 nb = 1202	avg = 0.03 std = 0.08 nb = 871	avg = -0.11 std = 0.04 nb = 80
Barrass 2	avg = -0.05 std = 0.05 nb = 1783	avg = -0.14 std = 0.06 nb = 1202	avg = -0.09 std = 0.09 nb = 871	avg = -0.25 std = 0.04 nb = 80
Simard	avg = -0.02 std = 0.04 nb = 1783	avg = -0.06 std = 0.06 nb = 1202	avg = 0.02 std = 0.08 nb = 871	avg = -0.11 std = 0.04 nb = 80

***John B. Aird* day 314 (JBA314)**

	0 - 5	5 - 6	6 - 7	7 +
raw	avg = 0.00 std = 0.00 nb = 0	avg = 0.46 std = 0.03 nb = 65	avg = 0.42 std = 0.05 nb = 1408	avg = 0.00 std = 0.00 nb = 0
area	avg = 0.00 std = 0.00 nb = 0	avg = 0.42 std = 0.03 nb = 65	avg = 0.40 std = 0.05 nb = 1408	avg = 0.00 std = 0.00 nb = 0
Tuck	avg = 0.00 std = 0.00 nb = 0	avg = 0.07 std = 0.03 nb = 65	avg = -0.00 std = 0.07 nb = 1408	avg = 0.00 std = 0.00 nb = 0
Barrass 2	avg = 0.00 std = 0.00 nb = 0	avg = -0.08 std = 0.03 nb = 65	avg = -0.18 std = 0.08 nb = 1408	avg = 0.00 std = 0.00 nb = 0
Simard	avg = 0.00 std = 0.00 nb = 0	avg = 0.02 std = 0.03 nb = 65	avg = -0.06 std = 0.07 nb = 1408	avg = 0.00 std = 0.00 nb = 0

Rt. Hon. Paul Martin **day 299 (PMA299)**

	0 - 5	5 - 6	6 - 7	7 +
raw	avg = 0.00 std = 0.00 nb = 0	avg = 0.44 std = 0.07 nb = 682	avg = 0.52 std = 0.06 nb = 915	avg = 0.00 std = 0.00 nb = 0
area	avg = 0.00 std = 0.00 nb = 0	avg = 0.41 std = 0.06 nb = 682	avg = 0.49 std = 0.06 nb = 915	avg = 0.00 std = 0.00 nb = 0
Tuck	avg = 0.00 std = 0.00 nb = 0	avg = 0.11 std = 0.04 nb = 682	avg = 0.05 std = 0.07 nb = 915	avg = 0.00 std = 0.00 nb = 0
Barrass 2	avg = 0.00 std = 0.00 nb = 0	avg = -0.03 std = 0.04 nb = 682	avg = -0.16 std = 0.07 nb = 915	avg = 0.00 std = 0.00 nb = 0
Simard	avg = 0.00 std = 0.00 nb = 0	avg = 0.07 std = 0.04 nb = 682	avg = -0.00 std = 0.07 nb = 915	avg = 0.00 std = 0.00 nb = 0

Rt. Hon. Paul Martin **day 310 (PMA310)**

	0 - 5	5 - 6	6 - 7	7 +
raw	avg = 0.24 std = 0.09 nb = 906	avg = 0.38 std = 0.10 nb = 176	avg = 0.44 std = 0.08 nb = 1262	avg = 0.36 std = 0.02 nb = 61
area	avg = 0.26 std = 0.08 nb = 906	avg = 0.40 std = 0.09 nb = 176	avg = 0.57 std = 0.11 nb = 1262	avg = 0.47 std = 0.04 nb = 61
Tuck	avg = 0.10 std = 0.06 nb = 906	avg = 0.07 std = 0.10 nb = 176	avg = 0.05 std = 0.09 nb = 1262	avg = -0.09 std = 0.04 nb = 61
Barrass 2	avg = 0.05 std = 0.05 nb = 906	avg = -0.05 std = 0.09 nb = 176	avg = -0.07 std = 0.09 nb = 1262	avg = -0.24 std = 0.04 nb = 61
Simard	avg = 0.09 std = 0.05 nb = 906	avg = 0.05 std = 0.09 nb = 176	avg = 0.06 std = 0.09 nb = 1262	avg = -0.08 std = 0.03 nb = 61

A.2 Statistics for ships of the same type

A.2.1 New Lakers

Algoville **day 316 (ALV316)**

	0 - 5	5 - 6	6 - 7	7 +
raw	avg = 0.16 std = 0.06 nb = 650	avg = 0.42 std = 0.07 nb = 355	avg = 0.53 std = 0.06 nb = 707	avg = 0.32 std = 0.01 nb = 9
area	avg = 0.15 std = 0.06 nb = 650	avg = 0.40 std = 0.07 nb = 355	avg = 0.52 std = 0.05 nb = 707	avg = 0.34 std = 0.02 nb = 9
Tuck	avg = 0.05 std = 0.04 nb = 650	avg = 0.08 std = 0.04 nb = 355	avg = 0.12 std = 0.05 nb = 707	avg = -0.19 std = 0.02 nb = 9
Barrass 2	avg = 0.00 std = 0.06 nb = 650	avg = -0.07 std = 0.03 nb = 355	avg = -0.05 std = 0.05 nb = 707	avg = -0.39 std = 0.03 nb = 9
Simard	avg = 0.03 std = 0.05 nb = 650	avg = 0.04 std = 0.04 nb = 355	avg = 0.09 std = 0.05 nb = 707	avg = -0.21 std = 0.03 nb = 9

CSL Niagara **day 315 (CNI315)**

	0 - 5	5 - 6	6 - 7	7 +
raw	avg = 0.14 std = 0.06 nb = 1294	avg = 0.30 std = 0.08 nb = 2154	avg = 0.00 std = 0.00 nb = 0	avg = 0.00 std = 0.00 nb = 0
area	avg = 0.16 std = 0.07 nb = 1294	avg = 0.33 std = 0.08 nb = 2154	avg = 0.00 std = 0.00 nb = 0	avg = 0.00 std = 0.00 nb = 0
Tuck	avg = -0.03 std = 0.04 nb = 1294	avg = -0.01 std = 0.07 nb = 2154	avg = 0.00 std = 0.00 nb = 0	avg = 0.00 std = 0.00 nb = 0
Barrass 2	avg = -0.09 std = 0.05 nb = 1294	avg = -0.13 std = 0.08 nb = 2154	avg = 0.00 std = 0.00 nb = 0	avg = 0.00 std = 0.00 nb = 0
Simard	avg = -0.03 std = 0.04 nb = 1294	avg = -0.03 std = 0.08 nb = 2154	avg = 0.00 std = 0.00 nb = 0	avg = 0.00 std = 0.00 nb = 0

***CSL Niagara* day 320 (CNI320)**

	0 - 5	5 - 6	6 - 7	7 +
raw	avg = 0.13 std = 0.10 nb = 1939	avg = 0.33 std = 0.07 nb = 2193	avg = 0.38 std = 0.08 nb = 435	avg = 0.00 std = 0.00 nb = 0
area	avg = 0.15 std = 0.12 nb = 1939	avg = 0.36 std = 0.07 nb = 2193	avg = 0.42 std = 0.11 nb = 435	avg = 0.00 std = 0.00 nb = 0
Tuck	avg = 0.01 std = 0.09 nb = 1939	avg = 0.02 std = 0.06 nb = 2193	avg = -0.01 std = 0.09 nb = 435	avg = 0.00 std = 0.00 nb = 0
Barrass 2	avg = -0.03 std = 0.11 nb = 1939	avg = -0.11 std = 0.09 nb = 2193	avg = -0.15 std = 0.10 nb = 435	avg = 0.00 std = 0.00 nb = 0
Simard	avg = 0.01 std = 0.10 nb = 1939	avg = 0.00 std = 0.08 nb = 2193	avg = -0.01 std = 0.10 nb = 435	avg = 0.00 std = 0.00 nb = 0

***Rt. Hon. Paul Martin* day 299 (PMA299)**

	0 - 5	5 - 6	6 - 7	7 +
raw	avg = 0.00 std = 0.00 nb = 0	avg = 0.44 std = 0.07 nb = 682	avg = 0.52 std = 0.06 nb = 915	avg = 0.00 std = 0.00 nb = 0
area	avg = 0.00 std = 0.00 nb = 0	avg = 0.41 std = 0.06 nb = 682	avg = 0.49 std = 0.06 nb = 915	avg = 0.00 std = 0.00 nb = 0
Tuck	avg = 0.00 std = 0.00 nb = 0	avg = 0.11 std = 0.04 nb = 682	avg = 0.05 std = 0.07 nb = 915	avg = 0.00 std = 0.00 nb = 0
Barrass 2	avg = 0.00 std = 0.00 nb = 0	avg = -0.03 std = 0.04 nb = 682	avg = -0.16 std = 0.07 nb = 915	avg = 0.00 std = 0.00 nb = 0
Simard	avg = 0.00 std = 0.00 nb = 0	avg = 0.07 std = 0.04 nb = 682	avg = -0.00 std = 0.07 nb = 915	avg = 0.00 std = 0.00 nb = 0

***Rt. Hon. Paul Martin* day 310 (PMA310)**

	0 - 5	5 - 6	6 - 7	7 +
raw	avg = 0.24 std = 0.09 nb = 906	avg = 0.38 std = 0.10 nb = 176	avg = 0.44 std = 0.08 nb = 1262	avg = 0.36 std = 0.02 nb = 61
area	avg = 0.26 std = 0.08 nb = 906	avg = 0.40 std = 0.09 nb = 176	avg = 0.57 std = 0.11 nb = 1262	avg = 0.47 std = 0.04 nb = 61
Tuck	avg = 0.10 std = 0.06 nb = 906	avg = 0.07 std = 0.10 nb = 176	avg = 0.05 std = 0.09 nb = 1262	avg = -0.09 std = 0.04 nb = 61
Barrass 2	avg = 0.05 std = 0.05 nb = 906	avg = -0.05 std = 0.09 nb = 176	avg = -0.07 std = 0.09 nb = 1262	avg = -0.24 std = 0.04 nb = 61
Simard	avg = 0.09 std = 0.05 nb = 906	avg = 0.05 std = 0.09 nb = 176	avg = 0.06 std = 0.09 nb = 1262	avg = -0.08 std = 0.03 nb = 61

A.2.2 Traditional Lakers

***Canadian Voyager* day 305 (CAV305)**

	0 - 5	5 - 6	6 - 7	7 +
raw	avg = 0.12 std = 0.06 nb = 1379	avg = 0.24 std = 0.06 nb = 494	avg = 0.41 std = 0.08 nb = 971	avg = 0.50 std = 0.07 nb = 410
area	avg = 0.15 std = 0.08 nb = 1379	avg = 0.31 std = 0.08 nb = 494	avg = 0.49 std = 0.09 nb = 971	avg = 0.53 std = 0.04 nb = 410
Tuck	avg = -0.02 std = 0.05 nb = 1379	avg = -0.00 std = 0.06 nb = 494	avg = 0.01 std = 0.06 nb = 971	avg = 0.02 std = 0.05 nb = 410
Barrass 2	avg = -0.06 std = 0.06 nb = 1379	avg = -0.09 std = 0.07 nb = 494	avg = -0.13 std = 0.07 nb = 971	avg = -0.17 std = 0.05 nb = 410
Simard	avg = -0.03 std = 0.05 nb = 1379	avg = -0.02 std = 0.07 nb = 494	avg = -0.01 std = 0.07 nb = 971	avg = -0.03 std = 0.04 nb = 410

***SS Halifax* day 308 (HAL308)**

	0 - 5	5 - 6	6 - 7	7 +
raw	avg = 0.14 std = 0.07 nb = 905	avg = 0.25 std = 0.04 nb = 152	avg = 0.49 std = 0.08 nb = 1857	avg = 0.46 std = 0.06 nb = 629
area	avg = 0.15 std = 0.08 nb = 905	avg = 0.29 std = 0.05 nb = 152	avg = 0.55 std = 0.11 nb = 1857	avg = 0.54 std = 0.08 nb = 629
Tuck	avg = 0.00 std = 0.04 nb = 905	avg = -0.02 std = 0.02 nb = 152	avg = 0.08 std = 0.07 nb = 1857	avg = -0.02 std = 0.07 nb = 629
Barrass 2	avg = -0.04 std = 0.05 nb = 905	avg = -0.12 std = 0.05 nb = 152	avg = -0.08 std = 0.08 nb = 1857	avg = -0.19 std = 0.08 nb = 629
Simard	avg = -0.01 std = 0.04 nb = 905	avg = -0.05 std = 0.04 nb = 152	avg = 0.04 std = 0.08 nb = 1857	avg = -0.05 std = 0.08 nb = 629

***Manitoulin* day 301 (MAN301)**

	0 - 5	5 - 6	6 - 7	7 +
raw	avg = 0.05 std = 0.07 nb = 2084	avg = 0.21 std = 0.06 nb = 971	avg = 0.28 std = 0.09 nb = 963	avg = 0.00 std = 0.00 nb = 0
area	avg = 0.05 std = 0.08 nb = 2084	avg = 0.26 std = 0.08 nb = 971	avg = 0.30 std = 0.10 nb = 963	avg = 0.00 std = 0.00 nb = 0
Tuck	avg = -0.09 std = 0.06 nb = 2084	avg = -0.06 std = 0.06 nb = 971	avg = -0.10 std = 0.07 nb = 963	avg = 0.00 std = 0.00 nb = 0
Barrass 2	avg = -0.14 std = 0.07 nb = 2084	avg = -0.15 std = 0.07 nb = 971	avg = -0.24 std = 0.07 nb = 963	avg = 0.00 std = 0.00 nb = 0
Simard	avg = -0.11 std = 0.07 nb = 2084	avg = -0.08 std = 0.07 nb = 971	avg = -0.14 std = 0.07 nb = 963	avg = 0.00 std = 0.00 nb = 0

A.2.3 Chemical Tankers

***Algosar* day 303 (ALS303)**

	0 - 5	5 - 6	6 - 7	7 +
raw	avg = 0.15 std = 0.05 nb = 319	avg = 0.34 std = 0.05 nb = 281	avg = 0.44 std = 0.09 nb = 1799	avg = 0.43 std = 0.12 nb = 217
area	avg = 0.15 std = 0.05 nb = 319	avg = 0.35 std = 0.04 nb = 281	avg = 0.52 std = 0.08 nb = 1799	avg = 0.59 std = 0.17 nb = 217
Tuck	avg = -0.05 std = 0.02 nb = 319	avg = -0.11 std = 0.04 nb = 281	avg = -0.15 std = 0.06 nb = 1799	avg = -0.20 std = 0.13 nb = 217
Barrass 2	avg = -0.01 std = 0.02 nb = 319	avg = -0.03 std = 0.03 nb = 281	avg = -0.04 std = 0.06 nb = 1799	avg = -0.05 std = 0.13 nb = 217
Simard	avg = -0.01 std = 0.02 nb = 319	avg = -0.01 std = 0.03 nb = 281	avg = 0.01 std = 0.06 nb = 1799	avg = 0.01 std = 0.13 nb = 217

***Algosar* day 316 (ALS316)**

	0 - 5	5 - 6	6 - 7	7 +
raw	avg = 0.15 std = 0.06 nb = 413	avg = 0.25 std = 0.12 nb = 771	avg = 0.32 std = 0.09 nb = 1787	avg = 0.35 std = 0.01 nb = 15
area	avg = 0.16 std = 0.07 nb = 413	avg = 0.30 std = 0.10 nb = 771	avg = 0.38 std = 0.07 nb = 1787	avg = 0.40 std = 0.01 nb = 15
Tuck	avg = -0.04 std = 0.04 nb = 413	avg = -0.12 std = 0.07 nb = 771	avg = -0.16 std = 0.07 nb = 1787	avg = -0.33 std = 0.05 nb = 15
Barrass 2	avg = -0.01 std = 0.04 nb = 413	avg = -0.07 std = 0.06 nb = 771	avg = -0.08 std = 0.06 nb = 1787	avg = -0.24 std = 0.04 nb = 15
Simard	avg = -0.00 std = 0.03 nb = 413	avg = -0.04 std = 0.07 nb = 771	avg = -0.04 std = 0.06 nb = 1787	avg = -0.19 std = 0.04 nb = 15

***Turid Knutson* day 317 (TUK317)**

	0 - 5	5 - 6	6 - 7	7 +
raw	avg = 0.11 std = 0.07 nb = 662	avg = 0.26 std = 0.08 nb = 121	avg = 0.53 std = 0.09 nb = 500	avg = 0.59 std = 0.09 nb = 1295
area	avg = 0.14 std = 0.09 nb = 662	avg = 0.31 std = 0.10 nb = 121	avg = 0.56 std = 0.09 nb = 500	avg = 0.71 std = 0.20 nb = 1295
Tuck	avg = -0.04 std = 0.06 nb = 662	avg = -0.10 std = 0.07 nb = 121	avg = -0.04 std = 0.06 nb = 500	avg = -0.08 std = 0.09 nb = 1295
Barrass 2	avg = -0.03 std = 0.05 nb = 662	avg = -0.09 std = 0.07 nb = 121	avg = -0.06 std = 0.07 nb = 500	avg = -0.09 std = 0.11 nb = 1295
Simard	avg = -0.01 std = 0.05 nb = 662	avg = -0.03 std = 0.07 nb = 121	avg = 0.04 std = 0.07 nb = 500	avg = 0.04 std = 0.11 nb = 1295

A.2.4 Salty Lakers

***Atlantic Erie* day 313 (ATE313)**

	0 - 5	5 - 6	6 - 7	7 +
raw	avg = 0.11 std = 0.07 nb = 1690	avg = 0.32 std = 0.07 nb = 431	avg = 0.36 std = 0.10 nb = 514	avg = 0.57 std = 0.02 nb = 66
area	avg = 0.13 std = 0.09 nb = 1690	avg = 0.38 std = 0.12 nb = 431	avg = 0.34 std = 0.09 nb = 514	avg = 0.54 std = 0.02 nb = 66
Tuck	avg = 0.03 std = 0.09 nb = 1690	avg = 0.03 std = 0.08 nb = 431	avg = -0.07 std = 0.06 nb = 514	avg = 0.05 std = 0.02 nb = 66
Barrass 2	avg = 0.01 std = 0.10 nb = 1690	avg = -0.07 std = 0.10 nb = 431	avg = -0.24 std = 0.05 nb = 514	avg = -0.17 std = 0.02 nb = 66
Simard	avg = 0.02 std = 0.09 nb = 1690	avg = 0.02 std = 0.10 nb = 431	avg = -0.12 std = 0.06 nb = 514	avg = -0.01 std = 0.02 nb = 66

Federal Fugi day 298 (FEF298)

	0 - 5	5 - 6	6 - 7	7 +
raw	avg = 0.09 std = 0.06 nb = 501	avg = 0.22 std = 0.06 nb = 139	avg = 0.37 std = 0.09 nb = 98	avg = 0.78 std = 0.15 nb = 2308
area	avg = 0.12 std = 0.08 nb = 501	avg = 0.29 std = 0.08 nb = 139	avg = 0.50 std = 0.13 nb = 98	avg = 0.89 std = 0.16 nb = 2308
Tuck	avg = -0.05 std = 0.05 nb = 501	avg = -0.07 std = 0.05 nb = 139	avg = -0.04 std = 0.07 nb = 98	avg = 0.11 std = 0.15 nb = 2308
Barrass 2	avg = -0.05 std = 0.05 nb = 501	avg = -0.08 std = 0.05 nb = 139	avg = -0.05 std = 0.07 nb = 98	avg = 0.05 std = 0.14 nb = 2308
Simard	avg = -0.04 std = 0.05 nb = 501	avg = -0.04 std = 0.05 nb = 139	avg = 0.02 std = 0.08 nb = 98	avg = 0.17 std = 0.13 nb = 2308

Federal Saguenay day 301 (FSA301)

	0 - 5	5 - 6	6 - 7	7 +
raw	avg = 0.00 std = 0.00 nb = 0	avg = 0.00 std = 0.00 nb = 0	avg = 0.00 std = 0.00 nb = 0	avg = 0.84 std = 0.15 nb = 504
area	avg = 0.00 std = 0.00 nb = 0	avg = 0.00 std = 0.00 nb = 0	avg = 0.00 std = 0.00 nb = 0	avg = 0.99 std = 0.16 nb = 504
Tuck	avg = 0.00 std = 0.00 nb = 0	avg = 0.00 std = 0.00 nb = 0	avg = 0.00 std = 0.00 nb = 0	avg = 0.30 std = 0.11 nb = 504
Barrass 2	avg = 0.00 std = 0.00 nb = 0	avg = 0.00 std = 0.00 nb = 0	avg = 0.00 std = 0.00 nb = 0	avg = 0.08 std = 0.11 nb = 504
Simard	avg = 0.00 std = 0.00 nb = 0	avg = 0.00 std = 0.00 nb = 0	avg = 0.00 std = 0.00 nb = 0	avg = 0.23 std = 0.11 nb = 504

John B. Aird day 306 (JBA306)

	0 - 5	5 - 6	6 - 7	7 +
raw	avg = 0.11 std = 0.06 nb = 1783	avg = 0.26 std = 0.06 nb = 1202	avg = 0.39 std = 0.08 nb = 871	avg = 0.34 std = 0.03 nb = 80
area	avg = 0.12 std = 0.06 nb = 1783	avg = 0.28 std = 0.07 nb = 1202	avg = 0.53 std = 0.11 nb = 871	avg = 0.45 std = 0.05 nb = 80
Tuck	avg = -0.01 std = 0.04 nb = 1783	avg = -0.02 std = 0.05 nb = 1202	avg = 0.03 std = 0.08 nb = 871	avg = -0.11 std = 0.04 nb = 80
Barrass 2	avg = -0.05 std = 0.05 nb = 1783	avg = -0.14 std = 0.06 nb = 1202	avg = -0.09 std = 0.09 nb = 871	avg = -0.25 std = 0.04 nb = 80
Simard	avg = -0.02 std = 0.04 nb = 1783	avg = -0.06 std = 0.06 nb = 1202	avg = 0.02 std = 0.08 nb = 871	avg = -0.11 std = 0.04 nb = 80

John B. Aird day 314 (JBA314)

	0 - 5	5 - 6	6 - 7	7 +
raw	avg = 0.00 std = 0.00 nb = 0	avg = 0.46 std = 0.03 nb = 65	avg = 0.42 std = 0.05 nb = 1408	avg = 0.00 std = 0.00 nb = 0
area	avg = 0.00 std = 0.00 nb = 0	avg = 0.42 std = 0.03 nb = 65	avg = 0.40 std = 0.05 nb = 1408	avg = 0.00 std = 0.00 nb = 0
Tuck	avg = 0.00 std = 0.00 nb = 0	avg = 0.07 std = 0.03 nb = 65	avg = -0.00 std = 0.07 nb = 1408	avg = 0.00 std = 0.00 nb = 0
Barrass 2	avg = 0.00 std = 0.00 nb = 0	avg = -0.08 std = 0.03 nb = 65	avg = -0.18 std = 0.08 nb = 1408	avg = 0.00 std = 0.00 nb = 0
Simard	avg = 0.00 std = 0.00 nb = 0	avg = 0.02 std = 0.03 nb = 65	avg = -0.06 std = 0.07 nb = 1408	avg = 0.00 std = 0.00 nb = 0

A.2.5 Salty Bulkers

Blade Runner **day 304 (BLR304)**

	0 - 5	5 - 6	6 - 7	7 +
raw	avg = 0.17 std = 0.08 nb = 989	avg = 0.31 std = 0.06 nb = 486	avg = 0.47 std = 0.11 nb = 1528	avg = 0.47 std = 0.11 nb = 431
area	avg = 0.19 std = 0.09 nb = 989	avg = 0.36 std = 0.08 nb = 486	avg = 0.52 std = 0.11 nb = 1528	avg = 0.58 std = 0.08 nb = 431
Tuck	avg = -0.00 std = 0.07 nb = 989	avg = -0.02 std = 0.06 nb = 486	avg = -0.03 std = 0.09 nb = 1528	avg = -0.07 std = 0.08 nb = 431
Barrass 2	avg = -0.00 std = 0.07 nb = 989	avg = -0.01 std = 0.06 nb = 486	avg = -0.02 std = 0.08 nb = 1528	avg = -0.07 std = 0.07 nb = 431
Simard	avg = 0.01 std = 0.07 nb = 989	avg = 0.02 std = 0.06 nb = 486	avg = 0.04 std = 0.08 nb = 1528	avg = 0.01 std = 0.07 nb = 431

Clipper Eagle **day 307 (CLE307)**

	0 - 5	5 - 6	6 - 7	7 +
raw	avg = 0.03 std = 0.05 nb = 2861	avg = 0.19 std = 0.04 nb = 1320	avg = 0.29 std = 0.05 nb = 35	avg = 0.59 std = 0.09 nb = 1028
area	avg = 0.05 std = 0.08 nb = 2861	avg = 0.31 std = 0.07 nb = 1320	avg = 0.36 std = 0.06 nb = 35	avg = 0.73 std = 0.12 nb = 1028
Tuck	avg = -0.02 std = 0.04 nb = 2861	avg = -0.06 std = 0.04 nb = 1320	avg = -0.11 std = 0.03 nb = 35	avg = -0.08 std = 0.05 nb = 1028
Barrass 2	avg = -0.02 std = 0.04 nb = 2861	avg = -0.05 std = 0.04 nb = 1320	avg = -0.16 std = 0.03 nb = 35	avg = -0.11 std = 0.06 nb = 1028
Simard	avg = -0.01 std = 0.03 nb = 2861	avg = -0.02 std = 0.04 nb = 1320	avg = -0.10 std = 0.03 nb = 35	avg = -0.01 std = 0.06 nb = 1028

Fossnes **day 304 (FOS304)**

	0 - 5	5 - 6	6 - 7	7 +
raw	avg = 0.10 std = 0.08 nb = 423	avg = 0.29 std = 0.07 nb = 241	avg = 0.54 std = 0.13 nb = 671	avg = 0.73 std = 0.12 nb = 1798
area	avg = 0.13 std = 0.10 nb = 423	avg = 0.35 std = 0.06 nb = 241	avg = 0.57 std = 0.15 nb = 671	avg = 0.84 std = 0.18 nb = 1798
Tuck	avg = -0.11 std = 0.06 nb = 423	avg = -0.13 std = 0.06 nb = 241	avg = -0.11 std = 0.10 nb = 671	avg = -0.08 std = 0.12 nb = 1798
Barrass 2	avg = -0.06 std = 0.06 nb = 423	avg = -0.05 std = 0.06 nb = 241	avg = 0.01 std = 0.10 nb = 671	avg = 0.08 std = 0.11 nb = 1798
Simard	avg = -0.04 std = 0.06 nb = 423	avg = -0.01 std = 0.05 nb = 241	avg = 0.07 std = 0.11 nb = 671	avg = 0.17 std = 0.11 nb = 1798

Lake Carling **day 315 (LAC315)**

	0 - 5	5 - 6	6 - 7	7 +
raw	avg = 0.05 std = 0.05 nb = 686	avg = 0.17 std = 0.07 nb = 352	avg = 0.35 std = 0.10 nb = 512	avg = 0.56 std = 0.14 nb = 1606
area	avg = 0.06 std = 0.06 nb = 686	avg = 0.20 std = 0.08 nb = 352	avg = 0.41 std = 0.09 nb = 512	avg = 0.61 std = 0.10 nb = 1606
Tuck	avg = -0.15 std = 0.06 nb = 686	avg = -0.15 std = 0.07 nb = 352	avg = -0.12 std = 0.06 nb = 512	avg = -0.11 std = 0.10 nb = 1606
Barrass 2	avg = -0.15 std = 0.06 nb = 686	avg = -0.16 std = 0.07 nb = 352	avg = -0.14 std = 0.06 nb = 512	avg = -0.16 std = 0.09 nb = 1606
Simard	avg = -0.12 std = 0.06 nb = 686	avg = -0.11 std = 0.07 nb = 352	avg = -0.06 std = 0.06 nb = 512	avg = -0.04 std = 0.08 nb = 1606

Mariupol day 297 (MAR297)

	0 - 5	5 - 6	6 - 7	7 +
raw	avg = 0.12 std = 0.05 nb = 352	avg = 0.22 std = 0.04 nb = 107	avg = 0.59 std = 0.12 nb = 1066	avg = 0.60 std = 0.12 nb = 1656
area	avg = 0.16 std = 0.06 nb = 352	avg = 0.30 std = 0.05 nb = 107	avg = 0.61 std = 0.11 nb = 1066	avg = 0.73 std = 0.12 nb = 1656
Tuck	avg = -0.04 std = 0.05 nb = 352	avg = -0.10 std = 0.05 nb = 107	avg = 0.09 std = 0.10 nb = 1066	avg = -0.01 std = 0.11 nb = 1656
Barrass 2	avg = -0.04 std = 0.05 nb = 352	avg = -0.09 std = 0.05 nb = 107	avg = 0.06 std = 0.09 nb = 1066	avg = -0.01 std = 0.10 nb = 1656
Simard	avg = -0.02 std = 0.05 nb = 352	avg = -0.04 std = 0.05 nb = 107	avg = 0.13 std = 0.09 nb = 1066	avg = 0.09 std = 0.10 nb = 1656

Millenium Raptor day 311 (MIR311)

	0 - 5	5 - 6	6 - 7	7 +
raw	avg = 0.03 std = 0.03 nb = 629	avg = 0.15 std = 0.06 nb = 385	avg = 0.20 std = 0.11 nb = 685	avg = 0.48 std = 0.13 nb = 278
area	avg = 0.04 std = 0.04 nb = 629	avg = 0.20 std = 0.07 nb = 385	avg = 0.25 std = 0.14 nb = 685	avg = 0.67 std = 0.18 nb = 278
Tuck	avg = -0.10 std = 0.06 nb = 629	avg = -0.14 std = 0.06 nb = 385	avg = -0.19 std = 0.10 nb = 685	avg = -0.10 std = 0.09 nb = 278
Barrass 2	avg = -0.11 std = 0.07 nb = 629	avg = -0.16 std = 0.06 nb = 385	avg = -0.22 std = 0.10 nb = 685	avg = -0.17 std = 0.09 nb = 278
Simard	avg = -0.10 std = 0.06 nb = 629	avg = -0.12 std = 0.06 nb = 385	avg = -0.16 std = 0.10 nb = 685	avg = -0.06 std = 0.09 nb = 278

Zoitsa S **day 302 (ZOS302)**

	0 - 5	5 - 6	6 - 7	7 +
raw	avg = 0.11 std = 0.11 nb = 458	avg = 0.31 std = 0.08 nb = 387	avg = 0.46 std = 0.12 nb = 335	avg = 0.67 std = 0.11 nb = 1927
area	avg = 0.12 std = 0.11 nb = 458	avg = 0.35 std = 0.07 nb = 387	avg = 0.53 std = 0.10 nb = 335	avg = 0.87 std = 0.13 nb = 1927
Tuck	avg = -0.08 std = 0.06 nb = 458	avg = -0.00 std = 0.07 nb = 387	avg = 0.04 std = 0.09 nb = 335	avg = 0.04 std = 0.12 nb = 1927
Barrass 2	avg = -0.09 std = 0.05 nb = 458	avg = -0.03 std = 0.06 nb = 387	avg = 0.00 std = 0.08 nb = 335	avg = 0.01 std = 0.11 nb = 1927
Simard	avg = -0.06 std = 0.06 nb = 458	avg = 0.01 std = 0.06 nb = 387	avg = 0.07 std = 0.08 nb = 335	avg = 0.12 std = 0.10 nb = 1927

A.3 Statistics for trends between ship types

A.1.1.1 Chemical Tanker

	0 - 5	5 - 6	6 - 7	7 +
raw	avg = 0.13 std = 0.07 nb = 1394	avg = 0.27 std = 0.11 nb = 1173	avg = 0.39 std = 0.12 nb = 4086	avg = 0.57 std = 0.11 nb = 1527
area	avg = 0.15 std = 0.08 nb = 1394	avg = 0.31 std = 0.10 nb = 1173	avg = 0.46 std = 0.11 nb = 4086	avg = 0.69 std = 0.20 nb = 1527
Tuck	avg = -0.04 std = 0.05 nb = 1394	avg = -0.12 std = 0.07 nb = 1173	avg = -0.14 std = 0.08 nb = 4086	avg = -0.10 std = 0.11 nb = 1527
Barrass 2	avg = -0.02 std = 0.04 nb = 1394	avg = -0.06 std = 0.06 nb = 1173	avg = -0.06 std = 0.06 nb = 4086	avg = -0.09 std = 0.11 nb = 1527
Simard	avg = -0.01 std = 0.04 nb = 1394	avg = -0.03 std = 0.06 nb = 1173	avg = -0.01 std = 0.07 nb = 4086	avg = 0.03 std = 0.11 nb = 1527

New Laker

	0 - 5	5 - 6	6 - 7	7 +
raw	avg = 0.16 std = 0.09 nb = 4789	avg = 0.34 std = 0.09 nb = 5560	avg = 0.47 std = 0.09 nb = 3319	avg = 0.35 std = 0.02 nb = 70
area	avg = 0.18 std = 0.10 nb = 4789	avg = 0.36 std = 0.08 nb = 5560	avg = 0.52 std = 0.10 nb = 3319	avg = 0.45 std = 0.06 nb = 70
Tuck	avg = 0.02 std = 0.08 nb = 4789	avg = 0.02 std = 0.08 nb = 5560	avg = 0.06 std = 0.09 nb = 3319	avg = -0.10 std = 0.05 nb = 70
Barrass 2	avg = -0.02 std = 0.09 nb = 4789	avg = -0.10 std = 0.08 nb = 5560	avg = -0.10 std = 0.09 nb = 3319	avg = -0.26 std = 0.06 nb = 70
Simard	avg = 0.02 std = 0.09 nb = 4789	avg = 0.00 std = 0.08 nb = 5560	avg = 0.04 std = 0.09 nb = 3319	avg = -0.09 std = 0.06 nb = 70

Salty Bulker

	0 - 5	5 - 6	6 - 7	7 +
raw	avg = 0.07 std = 0.08 nb = 6398	avg = 0.22 std = 0.08 nb = 3278	avg = 0.45 std = 0.17 nb = 4832	avg = 0.63 std = 0.14 nb = 8724
area	avg = 0.09 std = 0.10 nb = 6398	avg = 0.30 std = 0.09 nb = 3278	avg = 0.50 std = 0.16 nb = 4832	avg = 0.75 std = 0.17 nb = 8724
Tuck	avg = -0.05 std = 0.07 nb = 6398	avg = -0.07 std = 0.08 nb = 3278	avg = -0.04 std = 0.13 nb = 4832	avg = -0.05 std = 0.12 nb = 8724
Barrass 2	avg = -0.05 std = 0.07 nb = 6398	avg = -0.07 std = 0.08 nb = 3278	avg = -0.04 std = 0.13 nb = 4832	avg = -0.03 std = 0.13 nb = 8724
Simard	avg = -0.03 std = 0.07 nb = 6398	avg = -0.03 std = 0.07 nb = 3278	avg = 0.02 std = 0.13 nb = 4832	avg = 0.07 std = 0.12 nb = 8724

Salty Laker

	0 - 5	5 - 6	6 - 7	7 +
raw	avg = 0.10 std = 0.07 nb = 3974	avg = 0.28 std = 0.08 nb = 1837	avg = 0.40 std = 0.08 nb = 2891	avg = 0.78 std = 0.17 nb = 2958
area	avg = 0.12 std = 0.08 nb = 3974	avg = 0.31 std = 0.09 nb = 1837	avg = 0.43 std = 0.11 nb = 2891	avg = 0.89 std = 0.18 nb = 2958
Tuck	avg = 0.00 std = 0.07 nb = 3974	avg = -0.01 std = 0.07 nb = 1837	avg = -0.01 std = 0.08 nb = 2891	avg = 0.14 std = 0.16 nb = 2958
Barrass 2	avg = -0.03 std = 0.08 nb = 3974	avg = -0.12 std = 0.08 nb = 1837	avg = -0.16 std = 0.09 nb = 2891	avg = 0.04 std = 0.14 nb = 2958
Simard	avg = -0.00 std = 0.07 nb = 3974	avg = -0.04 std = 0.08 nb = 1837	avg = -0.04 std = 0.09 nb = 2891	avg = 0.17 std = 0.14 nb = 2958

Traditional Laker

	0 - 5	5 - 6	6 - 7	7 +
raw	avg = 0.09 std = 0.08 nb = 4368	avg = 0.22 std = 0.06 nb = 1617	avg = 0.42 std = 0.12 nb = 3791	avg = 0.47 std = 0.07 nb = 1039
area	avg = 0.11 std = 0.09 nb = 4368	avg = 0.28 std = 0.08 nb = 1617	avg = 0.47 std = 0.15 nb = 3791	avg = 0.54 std = 0.07 nb = 1039
Tuck	avg = -0.05 std = 0.07 nb = 4368	avg = -0.04 std = 0.07 nb = 1617	avg = 0.02 std = 0.10 nb = 3791	avg = -0.00 std = 0.06 nb = 1039
Barrass 2	avg = -0.09 std = 0.07 nb = 4368	avg = -0.13 std = 0.08 nb = 1617	avg = -0.13 std = 0.10 nb = 3791	avg = -0.18 std = 0.07 nb = 1039
Simard	avg = -0.06 std = 0.07 nb = 4368	avg = -0.06 std = 0.07 nb = 1617	avg = -0.02 std = 0.11 nb = 3791	avg = -0.04 std = 0.06 nb = 1039

B STATISTICS FOR LAKE ST. LOUIS

B.1 Statistics for ships passing twice

***Algosar* day 303 (ALS303)**

	0 - 7	7 - 9	9 - 11	11 +
raw	avg = 0.15 std = 0.06 nb = 683	avg = 0.27 std = 0.07 nb = 260	avg = 0.41 std = 0.19 nb = 238	avg = 0.50 std = 0.12 nb = 788
area	avg = 0.12 std = 0.05 nb = 683	avg = 0.27 std = 0.04 nb = 260	avg = 0.46 std = 0.10 nb = 238	avg = 0.55 std = 0.06 nb = 788
Tuck	avg = -0.02 std = 0.04 nb = 683	avg = -0.09 std = 0.05 nb = 260	avg = -0.10 std = 0.05 nb = 238	avg = -0.17 std = 0.07 nb = 788
Barrass 2	avg = -0.05 std = 0.05 nb = 683	avg = -0.13 std = 0.04 nb = 260	avg = -0.16 std = 0.05 nb = 238	avg = -0.23 std = 0.06 nb = 788
Simard	avg = -0.04 std = 0.04 nb = 683	avg = -0.10 std = 0.03 nb = 260	avg = -0.13 std = 0.08 nb = 238	avg = -0.18 std = 0.08 nb = 788

***Algosar* day 316 (ALS316)**

	0 - 7	7 - 9	9 - 11	11 +
raw	avg = 0.17 std = 0.04 nb = 80	avg = 0.34 std = 0.12 nb = 133	avg = 0.50 std = 0.13 nb = 489	avg = 0.55 std = 0.14 nb = 974
area	avg = 0.15 std = 0.07 nb = 80	avg = 0.35 std = 0.06 nb = 133	avg = 0.47 std = 0.08 nb = 489	avg = 0.61 std = 0.08 nb = 974
Tuck	avg = 0.04 std = 0.03 nb = 80	avg = 0.02 std = 0.03 nb = 133	avg = -0.01 std = 0.05 nb = 489	avg = -0.13 std = 0.06 nb = 974
Barrass 2	avg = -0.01 std = 0.02 nb = 80	avg = -0.06 std = 0.04 nb = 133	avg = -0.08 std = 0.06 nb = 489	avg = -0.19 std = 0.07 nb = 974
Simard	avg = -0.00 std = 0.03 nb = 80	avg = -0.04 std = 0.03 nb = 133	avg = -0.04 std = 0.08 nb = 489	avg = -0.15 std = 0.10 nb = 974

***CSL Niagara* day 315 (CNI315)**

	0 - 7	7 – 9	9 - 11	11 +
raw	avg = 0.17 std = 0.08 nb = 436	avg = 0.26 std = 0.04 nb = 277	avg = 0.30 std = 0.06 nb = 1217	avg = 0.33 std = 0.00 nb = 1
area	avg = 0.15 std = 0.08 nb = 436	avg = 0.30 std = 0.12 nb = 277	avg = 0.32 std = 0.10 nb = 1217	avg = 0.48 std = 0.00 nb = 1
Tuck	avg = 0.04 std = 0.07 nb = 436	avg = 0.04 std = 0.09 nb = 277	avg = -0.07 std = 0.08 nb = 1217	avg = 0.02 std = 0.00 nb = 1
Barrass 2	avg = -0.12 std = 0.11 nb = 436	avg = -0.19 std = 0.12 nb = 277	avg = -0.42 std = 0.10 nb = 1217	avg = -0.36 std = 0.00 nb = 1
Simard	avg = -0.05 std = 0.08 nb = 436	avg = -0.09 std = 0.07 nb = 277	avg = -0.24 std = 0.06 nb = 1217	avg = -0.23 std = 0.00 nb = 1

***CSL Niagara* day 320 (CNI320)**

	0 - 7	7 - 9	9 - 11	11 +
raw	avg = 0.04 std = 0.08 nb = 939	avg = 0.22 std = 0.06 nb = 643	avg = 0.23 std = 0.05 nb = 548	avg = 0.00 std = 0.00 nb = 0
area	avg = 0.04 std = 0.07 nb = 939	avg = 0.18 std = 0.04 nb = 643	avg = 0.24 std = 0.06 nb = 548	avg = 0.00 std = 0.00 nb = 0
Tuck	avg = -0.03 std = 0.04 nb = 939	avg = -0.06 std = 0.03 nb = 643	avg = -0.13 std = 0.06 nb = 548	avg = 0.00 std = 0.00 nb = 0
Barrass 2	avg = -0.11 std = 0.05 nb = 939	avg = -0.34 std = 0.06 nb = 643	avg = -0.49 std = 0.08 nb = 548	avg = 0.00 std = 0.00 nb = 0
Simard	avg = -0.08 std = 0.04 nb = 939	avg = -0.19 std = 0.03 nb = 643	avg = -0.31 std = 0.05 nb = 548	avg = 0.00 std = 0.00 nb = 0

John B. Aird day 306 (JBA306)

	0 - 7	7 - 9	9 - 11	11 +
raw	avg = 0.08 std = 0.05 nb = 768	avg = 0.14 std = 0.04 nb = 332	avg = 0.25 std = 0.07 nb = 1049	avg = 0.00 std = 0.00 nb = 0
area	avg = 0.08 std = 0.06 nb = 768	avg = 0.15 std = 0.05 nb = 332	avg = 0.27 std = 0.06 nb = 1049	avg = 0.00 std = 0.00 nb = 0
Tuck	avg = -0.02 std = 0.06 nb = 768	avg = -0.07 std = 0.05 nb = 332	avg = -0.08 std = 0.05 nb = 1049	avg = 0.00 std = 0.00 nb = 0
Barrass 2	avg = -0.13 std = 0.08 nb = 768	avg = -0.28 std = 0.08 nb = 332	avg = -0.41 std = 0.07 nb = 1049	avg = 0.00 std = 0.00 nb = 0
Simard	avg = -0.09 std = 0.06 nb = 768	avg = -0.21 std = 0.05 nb = 332	avg = -0.28 std = 0.04 nb = 1049	avg = 0.00 std = 0.00 nb = 0

John B. Aird day 314 (JBA314)

	0 - 7	7 - 9	9 - 11	11 +
raw	avg = 0.03 std = 0.08 nb = 454	avg = 0.21 std = 0.07 nb = 719	avg = 0.23 std = 0.05 nb = 1431	avg = 0.00 std = 0.00 nb = 0
area	avg = 0.02 std = 0.05 nb = 454	avg = 0.18 std = 0.04 nb = 719	avg = 0.23 std = 0.05 nb = 1431	avg = 0.00 std = 0.00 nb = 0
Tuck	avg = -0.02 std = 0.05 nb = 454	avg = -0.06 std = 0.05 nb = 719	avg = -0.10 std = 0.05 nb = 1431	avg = 0.00 std = 0.00 nb = 0
Barrass 2	avg = -0.10 std = 0.07 nb = 454	avg = -0.33 std = 0.10 nb = 719	avg = -0.41 std = 0.06 nb = 1431	avg = 0.00 std = 0.00 nb = 0
Simard	avg = -0.08 std = 0.06 nb = 454	avg = -0.22 std = 0.05 nb = 719	avg = -0.28 std = 0.04 nb = 1431	avg = 0.00 std = 0.00 nb = 0

Rt. Hon. Paul Martin day 299 (PMA299)

	0 - 7	7 - 9	9 - 11	11 +
raw	avg = 0.07 std = 0.10 nb = 781	avg = 0.24 std = 0.09 nb = 738	avg = 0.34 std = 0.09 nb = 1146	avg = 0.32 std = 0.04 nb = 120
area	avg = 0.06 std = 0.07 nb = 781	avg = 0.19 std = 0.05 nb = 738	avg = 0.33 std = 0.07 nb = 1146	avg = 0.42 std = 0.07 nb = 120
Tuck	avg = 0.01 std = 0.05 nb = 781	avg = -0.01 std = 0.05 nb = 738	avg = -0.05 std = 0.06 nb = 1146	avg = -0.02 std = 0.06 nb = 120
Barrass 2	avg = -0.06 std = 0.07 nb = 781	avg = -0.26 std = 0.08 nb = 738	avg = -0.42 std = 0.07 nb = 1146	avg = -0.43 std = 0.07 nb = 120
Simard	avg = -0.04 std = 0.05 nb = 781	avg = -0.14 std = 0.06 nb = 738	avg = -0.24 std = 0.05 nb = 1146	avg = -0.28 std = 0.05 nb = 120

Rt. Hon. Paul Martin day 310 (PMA310)

	0 - 7	7 - 9	9 - 11	11 +
raw	avg = 0.18 std = 0.05 nb = 268	avg = 0.27 std = 0.05 nb = 835	avg = 0.28 std = 0.06 nb = 979	avg = 0.00 std = 0.00 nb = 0
area	avg = 0.18 std = 0.06 nb = 268	avg = 0.24 std = 0.05 nb = 835	avg = 0.29 std = 0.04 nb = 979	avg = 0.00 std = 0.00 nb = 0
Tuck	avg = 0.10 std = 0.03 nb = 268	avg = 0.03 std = 0.05 nb = 835	avg = -0.04 std = 0.05 nb = 979	avg = 0.00 std = 0.00 nb = 0
Barrass 2	avg = 0.00 std = 0.09 nb = 268	avg = -0.22 std = 0.07 nb = 835	avg = -0.36 std = 0.06 nb = 979	avg = 0.00 std = 0.00 nb = 0
Simard	avg = 0.04 std = 0.06 nb = 268	avg = -0.10 std = 0.05 nb = 835	avg = -0.21 std = 0.05 nb = 979	avg = 0.00 std = 0.00 nb = 0

B.2 Statistics for ships of the same type

B.2.1 New Lakers

***Rt. Hon. Paul Martin* day 299 (PMA299)**

	0 - 7	7 - 9	9 - 11	11 +
raw	avg = 0.07 std = 0.10 nb = 781	avg = 0.24 std = 0.09 nb = 738	avg = 0.34 std = 0.09 nb = 1146	avg = 0.32 std = 0.04 nb = 120
area	avg = 0.06 std = 0.07 nb = 781	avg = 0.19 std = 0.05 nb = 738	avg = 0.33 std = 0.07 nb = 1146	avg = 0.42 std = 0.07 nb = 120
Tuck	avg = 0.01 std = 0.05 nb = 781	avg = -0.01 std = 0.05 nb = 738	avg = -0.05 std = 0.06 nb = 1146	avg = -0.02 std = 0.06 nb = 120
Barrass 2	avg = -0.06 std = 0.07 nb = 781	avg = -0.26 std = 0.08 nb = 738	avg = -0.42 std = 0.07 nb = 1146	avg = -0.43 std = 0.07 nb = 120
Simard	avg = -0.04 std = 0.05 nb = 781	avg = -0.14 std = 0.06 nb = 738	avg = -0.24 std = 0.05 nb = 1146	avg = -0.28 std = 0.05 nb = 120

***Rt. Hon. Paul Martin* day 310 (PMA310)**

	0 - 7	7 - 9	9 - 11	11 +
raw	avg = 0.18 std = 0.05 nb = 268	avg = 0.27 std = 0.05 nb = 835	avg = 0.28 std = 0.06 nb = 979	avg = 0.00 std = 0.00 nb = 0
area	avg = 0.18 std = 0.06 nb = 268	avg = 0.24 std = 0.05 nb = 835	avg = 0.29 std = 0.04 nb = 979	avg = 0.00 std = 0.00 nb = 0
Tuck	avg = 0.10 std = 0.03 nb = 268	avg = 0.03 std = 0.05 nb = 835	avg = -0.04 std = 0.05 nb = 979	avg = 0.00 std = 0.00 nb = 0
Barrass 2	avg = 0.00 std = 0.09 nb = 268	avg = -0.22 std = 0.07 nb = 835	avg = -0.36 std = 0.06 nb = 979	avg = 0.00 std = 0.00 nb = 0
Simard	avg = 0.04 std = 0.06 nb = 268	avg = -0.10 std = 0.05 nb = 835	avg = -0.21 std = 0.05 nb = 979	avg = 0.00 std = 0.00 nb = 0

***Algoville* day 316 (ALV316)**

	0 - 7	7 - 9	9 - 11	11 +
raw	avg = 0.11 std = 0.03 nb = 123	avg = 0.35 std = 0.09 nb = 323	avg = 0.44 std = 0.14 nb = 597	avg = 0.46 std = 0.09 nb = 707
area	avg = 0.11 std = 0.04 nb = 123	avg = 0.28 std = 0.04 nb = 323	avg = 0.41 std = 0.07 nb = 597	avg = 0.49 std = 0.08 nb = 707
Tuck	avg = 0.02 std = 0.03 nb = 123	avg = 0.07 std = 0.04 nb = 323	avg = 0.00 std = 0.08 nb = 597	avg = -0.02 std = 0.08 nb = 707
Barrass 2	avg = -0.09 std = 0.04 nb = 123	avg = -0.23 std = 0.06 nb = 323	avg = -0.36 std = 0.10 nb = 597	avg = -0.45 std = 0.09 nb = 707
Simard	avg = -0.05 std = 0.04 nb = 123	avg = -0.08 std = 0.03 nb = 323	avg = -0.16 std = 0.09 nb = 597	avg = -0.23 std = 0.08 nb = 707

***CSL Niagara* day 315 (CNI315)**

	0 - 7	7 - 9	9 - 11	11 +
raw	avg = 0.17 std = 0.08 nb = 436	avg = 0.26 std = 0.04 nb = 277	avg = 0.30 std = 0.06 nb = 1217	avg = 0.33 std = 0.00 nb = 1
area	avg = 0.15 std = 0.08 nb = 436	avg = 0.30 std = 0.12 nb = 277	avg = 0.32 std = 0.10 nb = 1217	avg = 0.48 std = 0.00 nb = 1
Tuck	avg = 0.04 std = 0.07 nb = 436	avg = 0.04 std = 0.09 nb = 277	avg = -0.07 std = 0.08 nb = 1217	avg = 0.02 std = 0.00 nb = 1
Barrass 2	avg = -0.12 std = 0.11 nb = 436	avg = -0.19 std = 0.12 nb = 277	avg = -0.42 std = 0.10 nb = 1217	avg = -0.36 std = 0.00 nb = 1
Simard	avg = -0.05 std = 0.08 nb = 436	avg = -0.09 std = 0.07 nb = 277	avg = -0.24 std = 0.06 nb = 1217	avg = -0.23 std = 0.00 nb = 1

***CSL Niagara* day 320 (CNI320)**

	0 - 7	7 - 9	9 - 11	11 +
raw	avg = 0.04 std = 0.08 nb = 939	avg = 0.22 std = 0.06 nb = 643	avg = 0.23 std = 0.05 nb = 548	avg = 0.00 std = 0.00 nb = 0
area	avg = 0.04 std = 0.07 nb = 939	avg = 0.18 std = 0.04 nb = 643	avg = 0.24 std = 0.06 nb = 548	avg = 0.00 std = 0.00 nb = 0
Tuck	avg = -0.03 std = 0.04 nb = 939	avg = -0.06 std = 0.03 nb = 643	avg = -0.13 std = 0.06 nb = 548	avg = 0.00 std = 0.00 nb = 0
Barrass 2	avg = -0.11 std = 0.05 nb = 939	avg = -0.34 std = 0.06 nb = 643	avg = -0.49 std = 0.08 nb = 548	avg = 0.00 std = 0.00 nb = 0
Simard	avg = -0.08 std = 0.04 nb = 939	avg = -0.19 std = 0.03 nb = 643	avg = -0.31 std = 0.05 nb = 548	avg = 0.00 std = 0.00 nb = 0

B.2.2 Traditional Lakers

***Canadian Voyager* day 305 (CAV305)**

	0 - 7	7 - 9	9 - 11	11 +
raw	avg = 0.05 std = 0.04 nb = 1524	avg = 0.15 std = 0.06 nb = 115	avg = 0.38 std = 0.08 nb = 292	avg = 0.45 std = 0.05 nb = 171
area	avg = 0.06 std = 0.05 nb = 1524	avg = 0.16 std = 0.05 nb = 115	avg = 0.34 std = 0.06 nb = 292	avg = 0.41 std = 0.04 nb = 171
Tuck	avg = -0.00 std = 0.04 nb = 1524	avg = -0.06 std = 0.03 nb = 115	avg = -0.06 std = 0.04 nb = 292	avg = -0.07 std = 0.05 nb = 171
Barrass 2	avg = -0.06 std = 0.05 nb = 1524	avg = -0.26 std = 0.05 nb = 115	avg = -0.40 std = 0.06 nb = 292	avg = -0.47 std = 0.05 nb = 171
Simard	avg = -0.05 std = 0.05 nb = 1524	avg = -0.19 std = 0.03 nb = 115	avg = -0.23 std = 0.04 nb = 292	avg = -0.26 std = 0.04 nb = 171

SS Halifax **day 308 (HAL308)**

	0 - 7	7 - 9	9 - 11	11 +
raw	avg = -0.00 std = 0.04 nb = 1367	avg = 0.23 std = 0.10 nb = 205	avg = 0.35 std = 0.07 nb = 739	avg = 0.35 std = 0.07 nb = 839
area	avg = -0.00 std = 0.06 nb = 1367	avg = 0.21 std = 0.05 nb = 205	avg = 0.30 std = 0.05 nb = 739	avg = 0.36 std = 0.06 nb = 839
Tuck	avg = -0.02 std = 0.03 nb = 1367	avg = 0.04 std = 0.06 nb = 205	avg = -0.07 std = 0.07 nb = 739	avg = -0.11 std = 0.06 nb = 839
Barrass 2	avg = -0.05 std = 0.03 nb = 1367	avg = -0.21 std = 0.08 nb = 205	avg = -0.43 std = 0.10 nb = 739	avg = -0.51 std = 0.07 nb = 839
Simard	avg = -0.05 std = 0.03 nb = 1367	avg = -0.13 std = 0.07 nb = 205	avg = -0.26 std = 0.08 nb = 739	avg = -0.34 std = 0.05 nb = 839

Manitoulin **day 310 (MAN301)**

	0 - 7	7 - 9	9 - 11	11 +
raw	avg = -0.02 std = 0.03 nb = 165	avg = 0.13 std = 0.07 nb = 317	avg = 0.17 std = 0.11 nb = 399	avg = 0.21 std = 0.07 nb = 832
area	avg = -0.03 std = 0.05 nb = 165	avg = 0.09 std = 0.05 nb = 317	avg = 0.14 std = 0.09 nb = 399	avg = 0.21 std = 0.05 nb = 832
Tuck	avg = -0.08 std = 0.02 nb = 165	avg = -0.11 std = 0.04 nb = 317	avg = -0.20 std = 0.07 nb = 399	avg = -0.30 std = 0.07 nb = 832
Barrass 2	avg = -0.17 std = 0.04 nb = 165	avg = -0.39 std = 0.07 nb = 317	avg = -0.53 std = 0.09 nb = 399	avg = -0.74 std = 0.09 nb = 832
Simard	avg = -0.15 std = 0.04 nb = 165	avg = -0.28 std = 0.04 nb = 317	avg = -0.39 std = 0.08 nb = 399	avg = -0.55 std = 0.06 nb = 832

B.2.3 Chemical Tankers

***Algosar* day 303 (ALS303)**

	0 - 7	7 - 9	9 - 11	11 +
raw	avg = 0.15	avg = 0.27	avg = 0.41	avg = 0.50
	std = 0.06	std = 0.07	std = 0.19	std = 0.12
	nb = 683	nb = 260	nb = 238	nb = 788
area	avg = 0.12	avg = 0.27	avg = 0.46	avg = 0.55
	std = 0.05	std = 0.04	std = 0.10	std = 0.06
	nb = 683	nb = 260	nb = 238	nb = 788
Tuck	avg = -0.02	avg = -0.09	avg = -0.10	avg = -0.17
	std = 0.04	std = 0.05	std = 0.05	std = 0.07
	nb = 683	nb = 260	nb = 238	nb = 788
Barrass 2	avg = -0.05	avg = -0.13	avg = -0.16	avg = -0.23
	std = 0.05	std = 0.04	std = 0.05	std = 0.06
	nb = 683	nb = 260	nb = 238	nb = 788
Simard	avg = -0.04	avg = -0.10	avg = -0.13	avg = -0.18
	std = 0.04	std = 0.03	std = 0.08	std = 0.08
	nb = 683	nb = 260	nb = 238	nb = 788

***Algosar* day 316 (ALS316)**

	0 - 7	7 - 9	9 - 11	11 +
raw	avg = 0.17	avg = 0.34	avg = 0.50	avg = 0.55
	std = 0.04	std = 0.12	std = 0.13	std = 0.14
	nb = 80	nb = 133	nb = 489	nb = 974
area	avg = 0.15	avg = 0.35	avg = 0.47	avg = 0.61
	std = 0.07	std = 0.06	std = 0.08	std = 0.08
	nb = 80	nb = 133	nb = 489	nb = 974
Tuck	avg = 0.04	avg = 0.02	avg = -0.01	avg = -0.13
	std = 0.03	std = 0.03	std = 0.05	std = 0.06
	nb = 80	nb = 133	nb = 489	nb = 974
Barrass 2	avg = -0.01	avg = -0.06	avg = -0.08	avg = -0.19
	std = 0.02	std = 0.04	std = 0.06	std = 0.07
	nb = 80	nb = 133	nb = 489	nb = 974
Simard	avg = -0.00	avg = -0.04	avg = -0.04	avg = -0.15
	std = 0.03	std = 0.03	std = 0.08	std = 0.10
	nb = 80	nb = 133	nb = 489	nb = 974

***Turid Knutson* day 317 (TUK317)**

	0 - 7	7 - 9	9 - 11	11 +
raw	avg = 0.08 std = 0.03 nb = 332	avg = 0.27 std = 0.08 nb = 173	avg = 0.43 std = 0.10 nb = 1186	avg = 0.44 std = 0.07 nb = 455
area	avg = 0.13 std = 0.06 nb = 332	avg = 0.29 std = 0.10 nb = 173	avg = 0.40 std = 0.09 nb = 1186	avg = 0.53 std = 0.10 nb = 455
Tuck	avg = 0.02 std = 0.04 nb = 332	avg = 0.02 std = 0.06 nb = 173	avg = -0.14 std = 0.08 nb = 1186	avg = -0.11 std = 0.07 nb = 455
Barrass 2	avg = -0.02 std = 0.05 nb = 332	avg = -0.14 std = 0.10 nb = 173	avg = -0.31 std = 0.08 nb = 1186	avg = -0.32 std = 0.06 nb = 455
Simard	avg = -0.02 std = 0.05 nb = 332	avg = -0.08 std = 0.06 nb = 173	avg = -0.18 std = 0.07 nb = 1186	avg = -0.22 std = 0.05 nb = 455

B.2.4 Salty Lakers

***Atlantic Erie* day 313 (ATE313)**

	0 - 7	7 - 9	9 - 11	11 +
raw	avg = 0.02 std = 0.03 nb = 2204	avg = 0.07 std = 0.04 nb = 85	avg = 0.33 std = 0.10 nb = 1012	avg = 0.36 std = 0.09 nb = 277
area	avg = 0.01 std = 0.03 nb = 2204	avg = 0.11 std = 0.05 nb = 85	avg = 0.30 std = 0.08 nb = 1012	avg = 0.39 std = 0.06 nb = 277
Tuck	avg = 0.00 std = 0.04 nb = 2204	avg = -0.06 std = 0.02 nb = 85	avg = -0.10 std = 0.07 nb = 1012	avg = -0.07 std = 0.06 nb = 277
Barrass 2	avg = -0.02 std = 0.07 nb = 2204	avg = -0.24 std = 0.04 nb = 85	avg = -0.46 std = 0.09 nb = 1012	avg = -0.47 std = 0.07 nb = 277
Simard	avg = -0.01 std = 0.06 nb = 2204	avg = -0.21 std = 0.03 nb = 85	avg = -0.28 std = 0.07 nb = 1012	avg = -0.30 std = 0.06 nb = 277

***Federal Fugi* day 298 (FEF298)**

	0 – 7	7 - 9	9 - 11	11 +
raw	avg = 0.04 std = 0.03 nb = 1156	avg = 0.24 std = 0.14 nb = 233	avg = 0.48 std = 0.16 nb = 419	avg = 0.53 std = 0.13 nb = 962
area	avg = 0.05 std = 0.05 nb = 1156	avg = 0.23 std = 0.06 nb = 233	avg = 0.41 std = 0.10 nb = 419	avg = 0.53 std = 0.10 nb = 962
Tuck	avg = 0.00 std = 0.03 nb = 1156	avg = 0.01 std = 0.09 nb = 233	avg = -0.04 std = 0.06 nb = 419	avg = -0.12 std = 0.08 nb = 962
Barrass 2	avg = -0.03 std = 0.04 nb = 1156	avg = -0.17 std = 0.08 nb = 233	avg = -0.29 std = 0.08 nb = 419	avg = -0.39 std = 0.08 nb = 962
Simard	avg = -0.03 std = 0.04 nb = 1156	avg = -0.13 std = 0.09 nb = 233	avg = -0.17 std = 0.08 nb = 419	avg = -0.25 std = 0.09 nb = 962

***Federal Saguenay* day 301 (FSA301)**

	0 – 7	7 - 9	9 - 11	11 +
raw	avg = 0.05 std = 0.03 nb = 678	avg = 0.23 std = 0.23 nb = 97	avg = 0.44 std = 0.18 nb = 329	avg = 0.44 std = 0.11 nb = 1209
area	avg = 0.08 std = 0.05 nb = 678	avg = 0.34 std = 0.16 nb = 97	avg = 0.43 std = 0.12 nb = 329	avg = 0.53 std = 0.09 nb = 1209
Tuck	avg = 0.03 std = 0.03 nb = 678	avg = 0.09 std = 0.16 nb = 97	avg = 0.03 std = 0.08 nb = 329	avg = -0.12 std = 0.11 nb = 1209
Barrass 2	avg = -0.00 std = 0.04 nb = 678	avg = -0.08 std = 0.11 nb = 97	avg = -0.28 std = 0.07 nb = 329	avg = -0.47 std = 0.11 nb = 1209
Simard	avg = -0.00 std = 0.05 nb = 678	avg = -0.06 std = 0.15 nb = 97	avg = -0.16 std = 0.09 nb = 329	avg = -0.33 std = 0.10 nb = 1209

John B. Aird **day 306 (JBA306)**

	0 - 7	7 - 9	9 - 11	11 +
raw	avg = 0.08 std = 0.05 nb = 768	avg = 0.14 std = 0.04 nb = 332	avg = 0.25 std = 0.07 nb = 1049	avg = 0.00 std = 0.00 nb = 0
area	avg = 0.08 std = 0.06 nb = 768	avg = 0.15 std = 0.05 nb = 332	avg = 0.27 std = 0.06 nb = 1049	avg = 0.00 std = 0.00 nb = 0
Tuck	avg = -0.02 std = 0.06 nb = 768	avg = -0.07 std = 0.05 nb = 332	avg = -0.08 std = 0.05 nb = 1049	avg = 0.00 std = 0.00 nb = 0
Barrass 2	avg = -0.13 std = 0.08 nb = 768	avg = -0.28 std = 0.08 nb = 332	avg = -0.41 std = 0.07 nb = 1049	avg = 0.00 std = 0.00 nb = 0
Simard	avg = -0.09 std = 0.06 nb = 768	avg = -0.21 std = 0.05 nb = 332	avg = -0.28 std = 0.04 nb = 1049	avg = 0.00 std = 0.00 nb = 0

John B. Aird **day 314 (JBA314)**

	0 - 7	7 - 9	9 - 11	11 +
raw	avg = 0.03 std = 0.08 nb = 454	avg = 0.21 std = 0.07 nb = 719	avg = 0.23 std = 0.05 nb = 1431	avg = 0.00 std = 0.00 nb = 0
area	avg = 0.02 std = 0.05 nb = 454	avg = 0.18 std = 0.04 nb = 719	avg = 0.23 std = 0.05 nb = 1431	avg = 0.00 std = 0.00 nb = 0
Tuck	avg = -0.02 std = 0.05 nb = 454	avg = -0.06 std = 0.05 nb = 719	avg = -0.10 std = 0.05 nb = 1431	avg = 0.00 std = 0.00 nb = 0
Barrass 2	avg = -0.10 std = 0.07 nb = 454	avg = -0.33 std = 0.10 nb = 719	avg = -0.41 std = 0.06 nb = 1431	avg = 0.00 std = 0.00 nb = 0
Simard	avg = -0.08 std = 0.06 nb = 454	avg = -0.22 std = 0.05 nb = 719	avg = -0.28 std = 0.04 nb = 1431	avg = 0.00 std = 0.00 nb = 0

B.2.5 Salty Bulkers

***Blade Runner* day 304 (BLR304)**

	0 - 7	7 - 9	9 - 11	11 +
raw	avg = 0.06 std = 0.03 nb = 746	avg = 0.25 std = 0.08 nb = 1536	avg = 0.19 std = 0.03 nb = 38	avg = 0.00 std = 0.00 nb = 0
area	avg = 0.09 std = 0.03 nb = 746	avg = 0.21 std = 0.05 nb = 1536	avg = 0.24 std = 0.03 nb = 38	avg = 0.00 std = 0.00 nb = 0
Tuck	avg = -0.01 std = 0.03 nb = 746	avg = -0.08 std = 0.06 nb = 1536	avg = -0.08 std = 0.03 nb = 38	avg = 0.00 std = 0.00 nb = 0
Barrass 2	avg = -0.05 std = 0.04 nb = 746	avg = -0.22 std = 0.06 nb = 1536	avg = -0.24 std = 0.03 nb = 38	avg = 0.00 std = 0.00 nb = 0
Simard	avg = -0.05 std = 0.04 nb = 746	avg = -0.16 std = 0.06 nb = 1536	avg = -0.21 std = 0.03 nb = 38	avg = 0.00 std = 0.00 nb = 0

***Clipper Eagle* day 307 (CLE307)**

	0 - 7	7 - 9	9 - 11	11 +
raw	avg = 0.07 std = 0.03 nb = 144	avg = 0.23 std = 0.12 nb = 97	avg = 0.40 std = 0.11 nb = 244	avg = 0.48 std = 0.09 nb = 1163
area	avg = 0.13 std = 0.04 nb = 144	avg = 0.27 std = 0.08 nb = 97	avg = 0.40 std = 0.08 nb = 244	avg = 0.59 std = 0.08 nb = 1163
Tuck	avg = -0.01 std = 0.02 nb = 144	avg = -0.03 std = 0.06 nb = 97	avg = -0.12 std = 0.06 nb = 244	avg = -0.20 std = 0.08 nb = 1163
Barrass 2	avg = -0.04 std = 0.03 nb = 144	avg = -0.14 std = 0.09 nb = 97	avg = -0.25 std = 0.06 nb = 244	avg = -0.30 std = 0.07 nb = 1163
Simard	avg = -0.06 std = 0.03 nb = 144	avg = -0.13 std = 0.07 nb = 97	avg = -0.18 std = 0.05 nb = 244	avg = -0.24 std = 0.08 nb = 1163

Fossnes **day 304 (FOS304)**

	0 - 7	7 - 9	9 - 11	11 +
raw	avg = 0.05 std = 0.03 nb = 546	avg = 0.31 std = 0.21 nb = 165	avg = 0.75 std = 0.23 nb = 437	avg = 0.82 std = 0.17 nb = 1109
area	avg = 0.05 std = 0.04 nb = 546	avg = 0.27 std = 0.08 nb = 165	avg = 0.62 std = 0.11 nb = 437	avg = 0.82 std = 0.10 nb = 1109
Tuck	avg = -0.01 std = 0.04 nb = 546	avg = 0.02 std = 0.09 nb = 165	avg = 0.04 std = 0.07 nb = 437	avg = -0.03 std = 0.11 nb = 1109
Barrass 2	avg = -0.03 std = 0.05 nb = 546	avg = -0.09 std = 0.07 nb = 165	avg = -0.04 std = 0.09 nb = 437	avg = -0.11 std = 0.12 nb = 1109
Simard	avg = -0.03 std = 0.05 nb = 546	avg = -0.05 std = 0.11 nb = 165	avg = 0.08 std = 0.13 nb = 437	avg = 0.02 std = 0.14 nb = 1109

Lake Carling **day 315 (LAC315)**

	0 - 7	7 - 9	9 - 11	11 +
raw	avg = 0.07 std = 0.06 nb = 581	avg = 0.16 std = 0.05 nb = 177	avg = 0.36 std = 0.08 nb = 1309	avg = 0.29 std = 0.06 nb = 317
area	avg = 0.07 std = 0.05 nb = 581	avg = 0.21 std = 0.06 nb = 177	avg = 0.33 std = 0.05 nb = 1309	avg = 0.32 std = 0.07 nb = 317
Tuck	avg = -0.01 std = 0.05 nb = 581	avg = -0.04 std = 0.04 nb = 177	avg = -0.18 std = 0.07 nb = 1309	avg = -0.21 std = 0.09 nb = 317
Barrass 2	avg = -0.07 std = 0.07 nb = 581	avg = -0.19 std = 0.07 nb = 177	avg = -0.40 std = 0.08 nb = 1309	avg = -0.46 std = 0.08 nb = 317
Simard	avg = -0.06 std = 0.06 nb = 581	avg = -0.16 std = 0.04 nb = 177	avg = -0.28 std = 0.06 nb = 1309	avg = -0.36 std = 0.06 nb = 317

Mariupol day 297 (MAR297)

	0 - 7	7 - 9	9 - 11	11 +
raw	avg = 0.04 std = 0.05 nb = 1573	avg = 0.25 std = 0.08 nb = 286	avg = 0.37 std = 0.09 nb = 1107	avg = 0.00 std = 0.00 nb = 0
area	avg = 0.04 std = 0.04 nb = 1573	avg = 0.21 std = 0.05 nb = 286	avg = 0.34 std = 0.05 nb = 1107	avg = 0.00 std = 0.00 nb = 0
Tuck	avg = -0.04 std = 0.05 nb = 1573	avg = -0.04 std = 0.08 nb = 286	avg = -0.10 std = 0.07 nb = 1107	avg = 0.00 std = 0.00 nb = 0
Barrass 2	avg = -0.08 std = 0.06 nb = 1573	avg = -0.19 std = 0.05 nb = 286	avg = -0.28 std = 0.06 nb = 1107	avg = 0.00 std = 0.00 nb = 0
Simard	avg = -0.07 std = 0.06 nb = 1573	avg = -0.12 std = 0.06 nb = 286	avg = -0.19 std = 0.07 nb = 1107	avg = 0.00 std = 0.00 nb = 0

Millenium Raptor day 311 (MIR311)

	0 - 7	7 - 9	9 - 11	11 +
raw	avg = 0.00 std = 0.00 nb = 0	avg = 0.00 std = 0.00 nb = 0	avg = 0.51 std = 0.07 nb = 101	avg = 0.51 std = 0.10 nb = 712
area	avg = 0.00 std = 0.00 nb = 0	avg = 0.00 std = 0.00 nb = 0	avg = 0.42 std = 0.06 nb = 101	avg = 0.47 std = 0.07 nb = 712
Tuck	avg = 0.00 std = 0.00 nb = 0	avg = 0.00 std = 0.00 nb = 0	avg = -0.04 std = 0.05 nb = 101	avg = -0.12 std = 0.09 nb = 712
Barrass 2	avg = 0.00 std = 0.00 nb = 0	avg = 0.00 std = 0.00 nb = 0	avg = -0.30 std = 0.05 nb = 101	avg = -0.43 std = 0.09 nb = 712
Simard	avg = 0.00 std = 0.00 nb = 0	avg = 0.00 std = 0.00 nb = 0	avg = -0.17 std = 0.05 nb = 101	avg = -0.29 std = 0.09 nb = 712

Zoitsa S day 302 (ZOS302)

	0 - 7	7 - 9	9 - 11	11 +
raw	avg = 0.02 std = 0.04 nb = 652	avg = 0.32 std = 0.19 nb = 140	avg = 0.55 std = 0.14 nb = 533	avg = 0.51 std = 0.10 nb = 792
area	avg = 0.02 std = 0.04 nb = 652	avg = 0.32 std = 0.08 nb = 140	avg = 0.52 std = 0.06 nb = 533	avg = 0.59 std = 0.07 nb = 792
Tuck	avg = -0.03 std = 0.04 nb = 652	avg = 0.08 std = 0.10 nb = 140	avg = 0.04 std = 0.06 nb = 533	avg = -0.02 std = 0.07 nb = 792
Barrass 2	avg = -0.07 std = 0.05 nb = 652	avg = -0.09 std = 0.07 nb = 140	avg = -0.16 std = 0.06 nb = 533	avg = -0.23 std = 0.06 nb = 792
Simard	avg = -0.07 std = 0.05 nb = 652	avg = -0.05 std = 0.10 nb = 140	avg = -0.07 std = 0.07 nb = 533	avg = -0.15 std = 0.06 nb = 792

B.3 Statistics for trends between ship types

Chemical Tanker

	0 - 7	7 - 9	9 - 11	11 +
raw	avg = 0.13 std = 0.06 nb = 1095	avg = 0.29 std = 0.09 nb = 566	avg = 0.44 std = 0.13 nb = 1913	avg = 0.51 std = 0.13 nb = 2217
area	avg = 0.13 std = 0.05 nb = 1095	avg = 0.30 std = 0.08 nb = 566	avg = 0.43 std = 0.09 nb = 1913	avg = 0.57 std = 0.08 nb = 2217
Tuck	avg = -0.00 std = 0.04 nb = 1095	avg = -0.03 std = 0.07 nb = 566	avg = -0.10 std = 0.09 nb = 1913	avg = -0.14 std = 0.07 nb = 2217
Barrass 2	avg = -0.04 std = 0.05 nb = 1095	avg = -0.12 std = 0.07 nb = 566	avg = -0.23 std = 0.12 nb = 1913	avg = -0.23 std = 0.08 nb = 2217
Simard	avg = -0.03 std = 0.05 nb = 1095	avg = -0.08 std = 0.05 nb = 566	avg = -0.13 std = 0.09 nb = 1913	avg = -0.17 std = 0.09 nb = 2217

New Laker

	0 - 7	7 - 9	9 - 11	11 +
raw	avg = 0.09 std = 0.10 nb = 2547	avg = 0.26 std = 0.08 nb = 2816	avg = 0.32 std = 0.10 nb = 4487	avg = 0.44 std = 0.10 nb = 828
area	avg = 0.08 std = 0.09 nb = 2547	avg = 0.23 std = 0.07 nb = 2816	avg = 0.32 std = 0.09 nb = 4487	avg = 0.48 std = 0.08 nb = 828
Tuck	avg = 0.01 std = 0.06 nb = 2547	avg = 0.00 std = 0.07 nb = 2816	avg = -0.06 std = 0.07 nb = 4487	avg = -0.02 std = 0.08 nb = 828
Barrass 2	avg = -0.08 std = 0.08 nb = 2547	avg = -0.26 std = 0.09 nb = 2816	avg = -0.41 std = 0.09 nb = 4487	avg = -0.45 std = 0.09 nb = 828
Simard	avg = -0.05 std = 0.06 nb = 2547	avg = -0.13 std = 0.07 nb = 2816	avg = -0.23 std = 0.07 nb = 4487	avg = -0.24 std = 0.08 nb = 828

Salty Bulker

	0 - 7	7 - 9	9 - 11	11 +
raw	avg = 0.05 std = 0.05 nb = 4242	avg = 0.25 std = 0.11 nb = 2401	avg = 0.44 std = 0.18 nb = 3769	avg = 0.57 std = 0.20 nb = 4093
area	avg = 0.05 std = 0.05 nb = 4242	avg = 0.22 std = 0.07 nb = 2401	avg = 0.40 std = 0.12 nb = 3769	avg = 0.61 std = 0.17 nb = 4093
Tuck	avg = -0.02 std = 0.04 nb = 4242	avg = -0.05 std = 0.08 nb = 2401	avg = -0.09 std = 0.11 nb = 3769	avg = -0.11 std = 0.12 nb = 4093
Barrass 2	avg = -0.06 std = 0.06 nb = 4242	avg = -0.19 std = 0.08 nb = 2401	avg = -0.28 std = 0.14 nb = 3769	avg = -0.27 std = 0.15 nb = 4093
Simard	avg = -0.06 std = 0.05 nb = 4242	avg = -0.14 std = 0.08 nb = 2401	avg = -0.17 std = 0.13 nb = 3769	avg = -0.17 std = 0.16 nb = 4093

Salty Laker

	0 - 7	7 - 9	9 - 11	11 +
raw	avg = 0.04 std = 0.05 nb = 5260	avg = 0.19 std = 0.11 nb = 1466	avg = 0.30 std = 0.13 nb = 4240	avg = 0.47 std = 0.13 nb = 2448
area	avg = 0.04 std = 0.05 nb = 5260	avg = 0.19 std = 0.08 nb = 1466	avg = 0.29 std = 0.10 nb = 4240	avg = 0.51 std = 0.10 nb = 2448
Tuck	avg = -0.00 std = 0.04 nb = 5260	avg = -0.04 std = 0.08 nb = 1466	avg = -0.08 std = 0.07 nb = 4240	avg = -0.11 std = 0.09 nb = 2448
Barrass 2	avg = -0.04 std = 0.07 nb = 5260	avg = -0.28 std = 0.12 nb = 1466	avg = -0.40 std = 0.09 nb = 4240	avg = -0.44 std = 0.11 nb = 2448
Simard	avg = -0.03 std = 0.06 nb = 5260	avg = -0.19 std = 0.08 nb = 1466	avg = -0.26 std = 0.07 nb = 4240	avg = -0.29 std = 0.10 nb = 2448

Traditional Laker

	0 - 7	7 - 9	9 - 11	11 +
raw	avg = 0.02 std = 0.05 nb = 3056	avg = 0.17 std = 0.09 nb = 637	avg = 0.30 std = 0.12 nb = 1430	avg = 0.30 std = 0.11 nb = 1842
area	avg = 0.03 std = 0.06 nb = 3056	avg = 0.14 std = 0.07 nb = 637	avg = 0.26 std = 0.10 nb = 1430	avg = 0.30 std = 0.10 nb = 1842
Tuck	avg = -0.02 std = 0.04 nb = 3056	avg = -0.05 std = 0.08 nb = 637	avg = -0.10 std = 0.09 nb = 1430	avg = -0.19 std = 0.12 nb = 1842
Barrass 2	avg = -0.06 std = 0.05 nb = 3056	avg = -0.31 std = 0.11 nb = 637	avg = -0.45 std = 0.10 nb = 1430	avg = -0.61 std = 0.14 nb = 1842
Simard	avg = -0.05 std = 0.05 nb = 3056	avg = -0.21 std = 0.08 nb = 637	avg = -0.29 std = 0.10 nb = 1430	avg = -0.43 std = 0.12 nb = 1842

C STATISTICS FOR LAKE ST. FRANCIS

C.1 Statistics for trends between ship types

Atlantic Erie day 313 (ATE313) (Salty Laker)

	0 - 8	8 - 9	9 - 10	10 +
raw	avg = 0.47 std = 0.07 nb = 53	avg = 0.48 std = 0.10 nb = 509	avg = 0.44 std = 0.09 nb = 2163	avg = 0.51 std = 0.03 nb = 177
area	avg = 0.46 std = 0.08 nb = 53	avg = 0.45 std = 0.07 nb = 509	avg = 0.44 std = 0.07 nb = 2163	avg = 0.49 std = 0.01 nb = 177
Tuck	avg = 0.27 std = 0.07 nb = 53	avg = 0.19 std = 0.07 nb = 509	avg = 0.13 std = 0.07 nb = 2163	avg = 0.13 std = 0.01 nb = 177
Barrass 2	avg = 0.04 std = 0.07 nb = 53	avg = -0.13 std = 0.07 nb = 509	avg = -0.23 std = 0.08 nb = 2163	avg = -0.29 std = 0.02 nb = 177
Simard	avg = 0.13 std = 0.07 nb = 53	avg = 0.02 std = 0.07 nb = 509	avg = -0.08 std = 0.07 nb = 2163	avg = -0.09 std = 0.01 nb = 177

SS Halifax day 308 (HAL308) (Traditional Laker)

	0 - 8	8 - 9	9 - 10	10 +
raw	avg = 0.54 std = 0.02 nb = 89	avg = 0.66 std = 0.11 nb = 534	avg = 0.68 std = 0.10 nb = 1427	avg = 0.81 std = 0.16 nb = 776
area	avg = 0.53 std = 0.05 nb = 89	avg = 0.55 std = 0.10 nb = 534	avg = 0.66 std = 0.09 nb = 1427	avg = 0.84 std = 0.16 nb = 776
Tuck	avg = 0.36 std = 0.02 nb = 89	avg = 0.36 std = 0.10 nb = 534	avg = 0.36 std = 0.08 nb = 1427	avg = 0.42 std = 0.11 nb = 776
Barrass 2	avg = 0.13 std = 0.02 nb = 89	avg = 0.03 std = 0.10 nb = 534	avg = -0.00 std = 0.08 nb = 1427	avg = -0.01 std = 0.10 nb = 776
Simard	avg = 0.22 std = 0.02 nb = 89	avg = 0.18 std = 0.09 nb = 534	avg = 0.14 std = 0.08 nb = 1427	avg = 0.17 std = 0.11 nb = 776

***Lake Carling* day 315 (LAC315) (Salty Bulker)**

	0 - 8	8 - 9	9 - 10	10 +
raw	avg = 0.40 std = 0.05 nb = 30	avg = 0.45 std = 0.06 nb = 463	avg = 0.38 std = 0.08 nb = 1442	avg = 0.47 std = 0.08 nb = 839
area	avg = 0.37 std = 0.06 nb = 30	avg = 0.39 std = 0.04 nb = 463	avg = 0.38 std = 0.06 nb = 1442	avg = 0.47 std = 0.06 nb = 839
Tuck	avg = 0.13 std = 0.05 nb = 30	avg = 0.08 std = 0.05 nb = 463	avg = -0.02 std = 0.06 nb = 1442	avg = -0.00 std = 0.04 nb = 839
Barrass 2	avg = -0.04 std = 0.05 nb = 30	avg = -0.14 std = 0.06 nb = 463	avg = -0.27 std = 0.07 nb = 1442	avg = -0.29 std = 0.04 nb = 839
Simard	avg = 0.03 std = 0.05 nb = 30	avg = -0.04 std = 0.06 nb = 463	avg = -0.16 std = 0.07 nb = 1442	avg = -0.16 std = 0.04 nb = 839

***Rt. Hon. Paul Martin* day 310 (PMA310) (New Laker)**

	0 - 8	8 - 9	9 - 10	10 +
raw	avg = 0.52 std = 0.06 nb = 2088	avg = 0.46 std = 0.05 nb = 746	avg = 0.00 std = 0.00 nb = 0	avg = 0.00 std = 0.00 nb = 0
area	avg = 0.46 std = 0.08 nb = 2088	avg = 0.50 std = 0.13 nb = 746	avg = 0.00 std = 0.00 nb = 0	avg = 0.00 std = 0.00 nb = 0
Tuck	avg = 0.31 std = 0.07 nb = 2088	avg = 0.20 std = 0.07 nb = 746	avg = 0.00 std = 0.00 nb = 0	avg = 0.00 std = 0.00 nb = 0
Barrass 2	avg = 0.11 std = 0.08 nb = 2088	avg = -0.04 std = 0.09 nb = 746	avg = 0.00 std = 0.00 nb = 0	avg = 0.00 std = 0.00 nb = 0
Simard	avg = 0.21 std = 0.07 nb = 2088	avg = 0.08 std = 0.07 nb = 746	avg = 0.00 std = 0.00 nb = 0	avg = 0.00 std = 0.00 nb = 0

D STATISTICS FOR WILEY-DONDERO CANAL

D.1 Statistics for trends between ship types

***Atlantic Erie* day 313 (ATE313) (Salty Laker)**

	0 - 6	6 - 8	8 - 10	10 +
raw	avg = 0.33 std = 0.20 nb = 267	avg = 0.20 std = 0.03 nb = 68	avg = 0.46 std = 0.17 nb = 763	avg = 0.23 std = 0.15 nb = 271
area	avg = 0.31 std = 0.19 nb = 267	avg = 0.18 std = 0.02 nb = 68	avg = 0.41 std = 0.15 nb = 763	avg = 0.32 std = 0.15 nb = 271
Tuck	avg = 0.27 std = 0.24 nb = 267	avg = -0.15 std = 0.05 nb = 68	avg = -0.16 std = 0.19 nb = 763	avg = -0.24 std = 0.18 nb = 271
Barrass 2	avg = 0.25 std = 0.26 nb = 267	avg = -0.25 std = 0.06 nb = 68	avg = -0.31 std = 0.19 nb = 763	avg = -0.50 std = 0.16 nb = 271
Simard	avg = 0.27 std = 0.25 nb = 267	avg = -0.14 std = 0.04 nb = 68	avg = -0.11 std = 0.18 nb = 763	avg = -0.35 std = 0.12 nb = 271

***SS Halifax* day 308 (HAL308) (Traditional Laker)**

	0 – 6	6 - 8	8 - 10	10 +
raw	avg = 0.22 std = 0.13 nb = 255	avg = 0.23 std = 0.05 nb = 246	avg = 0.51 std = 0.11 nb = 484	avg = 0.39 std = 0.08 nb = 278
area	avg = 0.22 std = 0.13 nb = 255	avg = 0.21 std = 0.04 nb = 246	avg = 0.49 std = 0.11 nb = 484	avg = 0.50 std = 0.12 nb = 278
Tuck	avg = 0.15 std = 0.18 nb = 255	avg = -0.07 std = 0.03 nb = 246	avg = -0.04 std = 0.13 nb = 484	avg = -0.18 std = 0.18 nb = 278
Barrass 2	avg = 0.12 std = 0.20 nb = 255	avg = -0.17 std = 0.04 nb = 246	avg = -0.20 std = 0.13 nb = 484	avg = -0.42 std = 0.14 nb = 278
Simard	avg = 0.14 std = 0.19 nb = 255	avg = -0.09 std = 0.03 nb = 246	avg = -0.04 std = 0.12 nb = 484	avg = -0.25 std = 0.08 nb = 278

***Lake Carling* day 315 (LAC315) (Salty Bulker)**

	0 - 6	6 - 8	8 - 10	10 +
raw	avg = 0.15 std = 0.10 nb = 830	avg = 0.32 std = 0.10 nb = 204	avg = 0.41 std = 0.13 nb = 425	avg = 0.36 std = 0.12 nb = 167
area	avg = 0.14 std = 0.10 nb = 830	avg = 0.29 std = 0.10 nb = 204	avg = 0.43 std = 0.10 nb = 425	avg = 0.45 std = 0.10 nb = 167
Tuck	avg = 0.01 std = 0.15 nb = 830	avg = -0.06 std = 0.09 nb = 204	avg = -0.15 std = 0.15 nb = 425	avg = -0.29 std = 0.16 nb = 167
Barrass 2	avg = 0.01 std = 0.15 nb = 830	avg = -0.06 std = 0.08 nb = 204	avg = -0.17 std = 0.12 nb = 425	avg = -0.37 std = 0.09 nb = 167
Simard	avg = 0.03 std = 0.14 nb = 830	avg = 0.01 std = 0.07 nb = 204	avg = -0.07 std = 0.11 nb = 425	avg = -0.26 std = 0.08 nb = 167

***Rt. Hon. Paul Martin* day 310 (PMA310) (New Laker)**

	0 - 6	6 - 8	8 - 10	10 +
raw	avg = 0.08 std = 0.08 nb = 1883	avg = 0.24 std = 0.05 nb = 297	avg = 0.24 std = 0.03 nb = 138	avg = 0.00 std = 0.00 nb = 0
area	avg = 0.09 std = 0.10 nb = 1883	avg = 0.22 std = 0.05 nb = 297	avg = 0.35 std = 0.14 nb = 138	avg = 0.00 std = 0.00 nb = 0
Tuck	avg = 0.02 std = 0.10 nb = 1883	avg = -0.15 std = 0.07 nb = 297	avg = -0.12 std = 0.16 nb = 138	avg = 0.00 std = 0.00 nb = 0
Barrass 2	avg = 0.01 std = 0.10 nb = 1883	avg = -0.23 std = 0.08 nb = 297	avg = -0.26 std = 0.13 nb = 138	avg = 0.00 std = 0.00 nb = 0
Simard	avg = 0.02 std = 0.09 nb = 1883	avg = -0.10 std = 0.07 nb = 297	avg = -0.15 std = 0.08 nb = 138	avg = 0.00 std = 0.00 nb = 0

E RESULTS OF STATISTICAL ANALYSIS FOR SOUTH SHORE CANAL

Summary (see section 1.3 of text for more details)

Values presented in tables of Appendices E, F, G, and H are the results of statistical tests on the average performed between two sailings of the same ship (E.1 and F.1), two ships of the same type (E.2 and F.2), and two ship types (E.3, F.3, G.1, H.1). The aim of this statistical analysis is to state quantitatively if one ship passing twice has the same squat behaviour during each sailing, or if two ships of the same type have the same squat behaviour, of if two ship types have the same trend. The average, standard deviation and sample size were first computed (Appendices A, B, C, and D) for each ship (or each trend) for each of the five squat related elements (“raw”, “area”, “Tuck”, “Barrass 2”, “Simard”) for each of the four speed class (e.g. 0-5, 5-6, 6-7, 7+). Using the average, standard deviation and sample size of each ship (or trend) and Equation 1.4, the Z_{exp} value was computed and then compared to the known values of the Normal distribution for a 95% probability. The Z_{exp} value of the test is given with a “pass" or “fail" success result. The starting hypothesis, i.e. the two averages are consistent, is accepted (“pass") if $-1.96 \le Z_{exp} \le 1.96$ and rejected ("fail") otherwise. In that case, the alternative hypothesis states that the two averages are not statistically the same and are therefore inconsistent. The further Z_{exp} is from the $[-1.96, 1.96]$ interval, the more inconsistent the two averages are. If there is less than 30 observations in one of the two samples, “n<30” appears instead of the result.

E.1 Results of statistical analysis for ships passing twice

		0 – 5	5 - 6	6 - 7	7 +
als303 & als316	raw	0.25 pass	17.78 fail	39.79 fail	n<30
	area	-2.58 fail	11.01 fail	53.33 fail	n<30
	Tuck	-5.12 fail	4.41 fail	6.52 fail	n<30
	Barrass 2	-2.76 fail	11.14 fail	19.30 fail	n<30
	Simard	-3.02 fail	11.68 fail	25.73 fail	n<30
cni315 & cni320	raw	4.64 fail	-13.45 fail	n<30	n<30
	area	1.99 fail	-13.23 fail	n<30	n<30
	Tuck	-16.68 fail	-10.65 fail	n<30	n<30
	Barrass 2	-21.25 fail	-10.56 fail	n<30	n<30
	Simard	-15.53 fail	-11.64 fail	n<30	n<30
jba306 & jba314	raw	n<30	-48.74 fail	-7.71 fail	n<30
	area	n<30	-35.88 fail	32.86 fail	n<30
	Tuck	n<30	-20.83 fail	11.19 fail	n<30
	Barrass 2	n<30	-14.01 fail	26.10 fail	n<30
	Simard	n<30	-19.07 fail	25.66 fail	n<30
pma299 & pma310	raw	n<30	7.69 fail	24.67 fail	n<30
	area	n<30	1.37 pass	-20.90 fail	n<30
	Tuck	n<30	5.79 fail	-1.58 pass	n<30
	Barrass 2	n<30	2.86 fail	-23.91 fail	n<30
	Simard	n<30	3.35 fail	-19.21 fail	n<30

E.2 Results of statistical analysis for ships of the same type

E.2.1 New Lakers

		0 - 5	5 - 6	6 - 7	7 +
alv316 & cni315	raw	7.34 fail	28.23 fail	n<30	n<30
	area	-3.54 fail	18.55 fail	n<30	n<30
	Tuck	38.51 fail	32.06 fail	n<30	n<30
	Barrass 2	31.31 fail	27.07 fail	n<30	n<30
	Simard	29.48 fail	25.01 fail	n<30	n<30
alv316 & cni320	raw	10.62 fail	21.38 fail	35.61 fail	n<30
	area	-1.11 pass	10.87 fail	17.89 fail	n<30
	Tuck	12.69 fail	25.06 fail	26.78 fail	n<30
	Barrass 2	7.60 fail	15.75 fail	19.31 fail	n<30
	Simard	7.61 fail	15.11 fail	19.89 fail	n<30
alv316 & pma299	raw	n<30	-4.46 fail	4.65 fail	n<30
	area	n<30	-1.71 pass	10.41 fail	n<30
	Tuck	n<30	-14.46 fail	22.26 fail	n<30
	Barrass 2	n<30	-16.61 fail	34.38 fail	n<30
	Simard	n<30	-11.79 fail	30.02 fail	n<30
alv316 & pma310	raw	-21.38 fail	4.82 fail	29.16 fail	n<30
	area	-32.38 fail	0.35 pass	-13.18 fail	n<30
	Tuck	-21.69 fail	0.85 pass	19.96 fail	n<30
	Barrass 2	-17.69 fail	-2.66 fail	6.58 fail	n<30
	Simard	-24.38 fail	-1.31 pass	7.14 fail	n<30
cni315 & cni320	raw	4.64 fail	-13.45 fail	n<30	n<30
	area	1.99 fail	-13.23 fail	n<30	n<30
	Tuck	-16.68 fail	-10.65 fail	n<30	n<30
	Barrass 2	-21.25 fail	-10.56 fail	n<30	n<30
	Simard	-15.53 fail	-11.64 fail	n<30	n<30
cni315 & pma299	raw	n<30	-42.92 fail	n<30	n<30
	area	n<30	-28.72 fail	n<30	n<30
	Tuck	n<30	-53.22 fail	n<30	n<30
	Barrass 2	n<30	-45.59 fail	n<30	n<30
	Simard	n<30	-42.38 fail	n<30	n<30
cni315 & pma310	raw	-29.69 fail	-10.03 fail	n<30	n<30
	area	-29.92 fail	-10.01 fail	n<30	n<30
	Tuck	-56.02 fail	-10.18 fail	n<30	n<30
	Barrass 2	-61.83 fail	-12.13 fail	n<30	n<30
	Simard	-58.78 fail	-11.31 fail	n<30	n<30
cni320 & pma299	raw	n<30	-34.88 fail	-32.32 fail	n<30
	area	n<30	-18.37 fail	-12.57 fail	n<30
	Tuck	n<30	-47.41 fail	-11.35 fail	n<30
	Barrass 2	n<30	-32.88 fail	0.76 pass	n<30
	Simard	n<30	-31.18 fail	-2.48 fail	n<30

cni320 & pma310	raw	-30.94 fail	-6.07 fail	-13.79 fail	n<30
	area	-28.49 fail	-5.61 fail	-24.39 fail	n<30
	Tuck	-30.34 fail	-7.27 fail	-12.35 fail	n<30
	Barrass 2	-25.86 fail	-8.31 fail	-14.50 fail	n<30
	Simard	-28.64 fail	-7.32 fail	-14.60 fail	n<30
pma299 & pma310	raw	n<30	7.69 fail	24.67 fail	n<30
	area	n<30	1.37 pass	-20.90 fail	n<30
	Tuck	n<30	5.79 fail	-1.58 pass	n<30
	Barrass 2	n<30	2.86 fail	-23.91 fail	n<30
	Simard	n<30	3.35 fail	-19.21 fail	n<30

E.2.2 Traditional Lakers

		0 - 5	5 - 6	6 - 7	7 +
cav305 & hal308	raw	-7.52 fail	-2.90 fail	-24.91 fail	9.66 fail
	area	-0.79 pass	3.98 fail	-15.59 fail	-2.03 fail
	Tuck	-12.22 fail	4.53 fail	-24.89 fail	8.24 fail
	Barrass 2	-9.77 fail	6.84 fail	-17.44 fail	4.62 fail
	Simard	-8.41 fail	6.08 fail	-19.02 fail	4.47 fail
cav305 & man301	raw	32.18 fail	9.57 fail	34.39 fail	n<30
	area	34.59 fail	10.26 fail	42.38 fail	n<30
	Tuck	36.06 fail	17.06 fail	39.56 fail	n<30
	Barrass 2	35.67 fail	16.94 fail	34.52 fail	n<30
	Simard	38.11 fail	15.57 fail	38.35 fail	n<30
hal308 & man301	raw	34.70 fail	12.11 fail	60.58 fail	n<30
	area	32.32 fail	4.74 fail	59.95 fail	n<30
	Tuck	48.48 fail	16.81 fail	63.89 fail	n<30
	Barrass 2	45.34 fail	7.02 fail	54.05 fail	n<30
	Simard	45.86 fail	7.36 fail	58.82 fail	n<30

E.2.3 Chemical Tankers

		0 - 5	5 - 6	6 - 7	7 +
als303 & als316	raw	0.25 pass	17.78 fail	39.79 fail	n<30
	area	-2.58 fail	11.01 fail	53.33 fail	n<30
	Tuck	-5.12 fail	4.41 fail	6.52 fail	n<30
	Barrass 2	-2.76 fail	11.14 fail	19.30 fail	n<30
	Simard	-3.02 fail	11.68 fail	25.73 fail	n<30
als303 & tuk317	raw	12.36 fail	10.05 fail	-21.25 fail	-18.69 fail
	area	2.17 fail	3.86 fail	-9.33 fail	-9.29 fail
	Tuck	-4.10 fail	-1.00 pass	-34.38 fail	-13.61 fail
	Barrass 2	7.48 fail	8.33 fail	6.99 fail	4.80 fail
	Simard	1.15 pass	3.87 fail	-10.21 fail	-3.26 fail

als316 & tuk317	raw	11.61 fail	-2.07 fail	-47.95 fail	n<30
	area	4.38 fail	-1.36 pass	-40.77 fail	n<30
	Tuck	0.81 pass	-3.42 fail	-37.66 fail	n<30
	Barrass 2	8.48 fail	3.15 fail	-5.23 fail	n<30
	Simard	3.20 fail	-1.47 pass	-25.87 fail	n<30

E.2.4 Salty Lakers

		0 - 5	5 - 6	6 - 7	7 +
ate313 & fef298	raw	4.60 fail	16.51 fail	-1.13 pass	-52.04 fail
	area	2.11 fail	9.71 fail	-11.80 fail	-83.56 fail
	Tuck	26.94 fail	18.07 fail	-3.68 fail	-15.95 fail
	Barrass 2	18.63 fail	2.36 fail	-24.67 fail	-58.87 fail
	Simard	19.58 fail	7.95 fail	-16.90 fail	-49.31 fail
ate313 & fsa301	raw	n<30	n<30	n<30	-36.90 fail
	area	n<30	n<30	n<30	-58.55 fail
	Tuck	n<30	n<30	n<30	-44.78 fail
	Barrass 2	n<30	n<30	n<30	-44.77 fail
	Simard	n<30	n<30	n<30	-43.31 fail
ate313 & jba306	raw	-0.56 pass	14.20 fail	-6.26 fail	56.08 fail
	area	4.12 fail	15.99 fail	-34.38 fail	15.54 fail
	Tuck	15.86 fail	12.07 fail	-24.75 fail	29.56 fail
	Barrass 2	21.05 fail	13.58 fail	-40.05 fail	18.17 fail
	Simard	19.29 fail	14.20 fail	-36.55 fail	21.14 fail
ate313 & jba314	raw	n<30	-28.75 fail	-12.65 fail	n<30
	area	n<30	-6.07 fail	-13.44 fail	n<30
	Tuck	n<30	-7.02 fail	-18.31 fail	n<30
	Barrass 2	n<30	2.00 fail	-17.63 fail	n<30
	Simard	n<30	-1.06 pass	-16.63 fail	n<30
fef298 & fsa301	raw	n<30	n<30	n<30	-7.30 fail
	area	n<30	n<30	n<30	-12.30 fail
	Tuck	n<30	n<30	n<30	-31.14 fail
	Barrass 2	n<30	n<30	n<30	-4.34 fail
	Simard	n<30	n<30	n<30	-11.28 fail
fef298 & jba306	raw	-5.26 fail	-8.40 fail	-2.03 fail	96.90 fail
	area	0.40 pass	1.86 pass	-2.19 fail	68.12 fail
	Tuck	-18.99 fail	-11.98 fail	-8.98 fail	39.37 fail
	Barrass 2	-0.51 pass	11.29 fail	5.08 fail	60.51 fail
	Simard	-5.18 fail	4.11 fail	-0.54 pass	58.11 fail
fef298 & jba314	raw	n<30	-39.64 fail	-4.62 fail	n<30
	area	n<30	-17.08 fail	8.04 fail	n<30
	Tuck	n<30	-24.14 fail	-4.30 fail	n<30
	Barrass 2	n<30	-0.57 pass	17.69 fail	n<30
	Simard	n<30	-10.00 fail	10.61 fail	n<30

fsa301 & jba306	raw	n<30	n<30	n<30	67.07 fail
	area	n<30	n<30	n<30	59.40 fail
	Tuck	n<30	n<30	n<30	59.83 fail
	Barrass 2	n<30	n<30	n<30	51.47 fail
	Simard	n<30	n<30	n<30	53.22 fail
fsa301 & jba314	raw	n<30	n<30	n<30	n<30
	area	n<30	n<30	n<30	n<30
	Tuck	n<30	n<30	n<30	n<30
	Barrass 2	n<30	n<30	n<30	n<30
	Simard	n<30	n<30	n<30	n<30
jba306 & jba314	raw	n<30	-48.74 fail	-7.71 fail	n<30
	area	n<30	-35.88 fail	32.86 fail	n<30
	Tuck	n<30	-20.83 fail	11.19 fail	n<30
	Barrass 2	n<30	-14.01 fail	26.10 fail	n<30
	Simard	n<30	-19.07 fail	25.66 fail	n<30

E.2.5 Salty Bulkers

		0 - 5	5 - 6	6 - 7	7 +
blr304 & cle307	raw	54.14 fail	38.88 fail	22.27 fail	-20.31 fail
	area	42.58 fail	11.53 fail	16.12 fail	-28.06 fail
	Tuck	6.75 fail	16.84 fail	13.77 fail	4.29 fail
	Barrass 2	5.08 fail	12.96 fail	21.26 fail	11.49 fail
	Simard	9.46 fail	15.85 fail	22.28 fail	5.31 fail
blr304 & fos304	raw	16.30 fail	3.18 fail	-11.81 fail	-44.66 fail
	area	10.88 fail	2.22 fail	-8.42 fail	-44.81 fail
	Tuck	27.74 fail	24.80 fail	18.00 fail	3.61 fail
	Barrass 2	14.89 fail	7.83 fail	-6.91 fail	-32.78 fail
	Simard	13.66 fail	6.47 fail	-7.77 fail	-37.15 fail
blr304 & lac315	raw	40.99 fail	29.90 fail	22.12 fail	-15.05 fail
	area	35.28 fail	27.40 fail	23.30 fail	-5.31 fail
	Tuck	46.93 fail	30.88 fail	27.69 fail	10.28 fail
	Barrass 2	45.43 fail	31.96 fail	35.74 fail	21.85 fail
	Simard	41.98 fail	29.70 fail	29.78 fail	11.81 fail
blr304 & mar297	raw	15.96 fail	18.15 fail	-25.77 fail	-22.31 fail
	area	7.72 fail	10.12 fail	-21.29 fail	-29.63 fail
	Tuck	11.10 fail	14.36 fail	-30.56 fail	-11.76 fail
	Barrass 2	9.37 fail	12.90 fail	-24.32 fail	-13.94 fail
	Simard	8.07 fail	11.97 fail	-27.50 fail	-19.45 fail
blr304 & mir311	raw	51.31 fail	37.87 fail	54.66 fail	-1.53 pass
	area	44.71 fail	30.43 fail	44.55 fail	-7.67 fail
	Tuck	30.05 fail	29.12 fail	36.19 fail	4.88 fail
	Barrass 2	31.02 fail	35.63 fail	46.55 fail	16.74 fail
	Simard	32.38 fail	34.39 fail	45.55 fail	10.55 fail

blr304 & zos302	raw	11.61 fail	-0.56 pass	1.31 pass	-35.79 fail
	area	11.79 fail	2.24 fail	-1.92 pass	-59.37 fail
	Tuck	21.98 fail	-4.12 fail	-12.52 fail	-21.75 fail
	Barrass 2	25.15 fail	5.10 fail	-5.15 fail	-18.83 fail
	Simard	21.84 fail	3.32 fail	-5.90 fail	-27.15 fail
cle307 & fos304	raw	-17.41 fail	-22.57 fail	-27.50 fail	-35.03 fail
	area	-15.21 fail	-8.25 fail	-19.20 fail	-19.35 fail
	Tuck	28.05 fail	16.77 fail	-0.36 pass	-0.22 pass
	Barrass 2	14.31 fail	-0.78 pass	-22.94 fail	-58.91 fail
	Simard	9.45 fail	-4.98 fail	-24.21 fail	-55.70 fail
cle307 & lac315	raw	-6.50 fail	5.45 fail	-7.47 fail	5.50 fail
	area	-2.09 fail	23.22 fail	-5.24 fail	28.44 fail
	Tuck	54.49 fail	23.45 fail	1.40 pass	10.21 fail
	Barrass 2	55.26 fail	27.75 fail	-2.47 fail	16.07 fail
	Simard	47.19 fail	23.01 fail	-6.23 fail	9.52 fail
cle307 & mar297	raw	-32.36 fail	-9.77 fail	-35.74 fail	-2.89 fail
	area	-29.36 fail	2.35 fail	-24.78 fail	1.24 pass
	Tuck	8.27 fail	6.77 fail	-31.08 fail	-23.45 fail
	Barrass 2	7.52 fail	7.14 fail	-33.17 fail	-34.98 fail
	Simard	2.01 fail	4.01 fail	-36.08 fail	-33.90 fail
cle307 & mir311	raw	1.27 pass	11.75 fail	10.45 fail	12.92 fail
	area	5.64 fail	27.25 fail	9.25 fail	4.98 fail
	Tuck	31.86 fail	21.07 fail	11.19 fail	2.64 fail
	Barrass 2	34.47 fail	32.33 fail	9.84 fail	10.94 fail
	Simard	33.76 fail	28.59 fail	8.87 fail	8.21 fail
cle307 & zos302	raw	-14.38 fail	-28.43 fail	-17.37 fail	-22.11 fail
	area	-12.49 fail	-9.11 fail	-15.57 fail	-30.09 fail
	Tuck	21.54 fail	-17.46 fail	-20.21 fail	-39.62 fail
	Barrass 2	28.18 fail	-5.67 fail	-21.42 fail	-41.88 fail
	Simard	19.79 fail	-10.72 fail	-22.69 fail	-45.19 fail
fos304 & Lac315	raw	12.69 fail	21.42 fail	28.02 fail	36.59 fail
	area	13.16 fail	24.59 fail	23.89 fail	47.52 fail
	Tuck	11.52 fail	3.84 fail	2.41 fail	8.14 fail
	Barrass 2	25.03 fail	21.61 fail	31.00 fail	66.96 fail
	Simard	22.97 fail	21.10 fail	27.22 fail	61.21 fail
fos304 & Mar297	raw	-3.96 fail	11.69 fail	-8.93 fail	32.04 fail
	area	-4.77 fail	7.88 fail	-6.01 fail	22.15 fail
	Tuck	-15.38 fail	-4.97 fail	-39.74 fail	-18.81 fail
	Barrass 2	-5.36 fail	6.54 fail	-10.56 fail	23.73 fail
	Simard	-5.93 fail	6.40 fail	-11.53 fail	22.78 fail
fos304 & Mir311	raw	17.39 fail	26.20 fail	53.69 fail	30.38 fail
	area	17.48 fail	27.34 fail	41.31 fail	14.00 fail
	Tuck	-0.82 pass	0.79 pass	14.42 fail	2.57 fail
	Barrass 2	14.07 fail	23.78 fail	41.91 fail	42.50 fail
	Simard	15.17 fail	24.38 fail	41.22 fail	37.53 fail

fos304 & zos302	raw	-1.14 pass	-3.23 fail	9.48 fail	14.65 fail
	area	1.28 pass	-0.09 pass	5.11 fail	-6.63 fail
	Tuck	-6.57 fail	-25.35 fail	-23.67 fail	-31.41 fail
	Barrass 2	7.58 fail	-3.23 fail	1.05 pass	17.91 fail
	Simard	6.41 fail	-3.39 fail	1.20 pass	14.45 fail
lac315 & mar297	raw	-22.87 fail	-11.13 fail	-41.44 fail	-8.06 fail
	area	-24.51 fail	-15.19 fail	-40.02 fail	-31.34 fail
	Tuck	-29.61 fail	-8.34 fail	-53.14 fail	-28.21 fail
	Barrass 2	-31.77 fail	-10.71 fail	-53.50 fail	-45.52 fail
	Simard	-31.51 fail	-11.08 fail	-51.21 fail	-40.74 fail
lac315 & mir311	raw	6.79 fail	3.31 fail	26.19 fail	9.50 fail
	area	6.36 fail	1.30 pass	24.24 fail	-5.81 fail
	Tuck	-13.74 fail	-3.39 fail	14.92 fail	-2.26 fail
	Barrass 2	-10.11 fail	0.66 pass	18.49 fail	2.51 fail
	Simard	-8.16 fail	1.75 pass	21.91 fail	3.57 fail
lac315 & zos302	raw	-11.14 fail	-25.68 fail	-13.84 fail	-25.14 fail
	area	-10.77 fail	-25.89 fail	-17.80 fail	-68.47 fail
	Tuck	-19.81 fail	-30.53 fail	-29.02 fail	-42.05 fail
	Barrass 2	-19.14 fail	-26.78 fail	-27.85 fail	-51.72 fail
	Simard	-17.30 fail	-26.09 fail	-24.60 fail	-51.56 fail
mar297 & mir311	raw	31.03 fail	15.78 fail	71.79 fail	14.37 fail
	area	31.90 fail	17.17 fail	57.30 fail	4.56 fail
	Tuck	15.92 fail	5.93 fail	56.58 fail	14.33 fail
	Barrass 2	19.94 fail	11.69 fail	60.63 fail	28.58 fail
	Simard	22.81 fail	13.04 fail	62.00 fail	24.89 fail
mar297 & zos302	raw	1.86 pass	-15.69 fail	17.69 fail	-19.01 fail
	area	6.00 fail	-8.31 fail	12.19 fail	-35.25 fail
	Tuck	9.40 fail	-16.07 fail	8.19 fail	-12.05 fail
	Barrass 2	13.67 fail	-9.36 fail	11.14 fail	-6.14 fail
	Simard	13.16 fail	-9.45 fail	12.45 fail	-9.44 fail
mir311 & zos302	raw	-14.52 fail	-31.13 fail	-34.84 fail	-23.74 fail
	area	-14.67 fail	-28.94 fail	-35.93 fail	-17.47 fail
	Tuck	-6.31 fail	-28.74 fail	-36.52 fail	-21.91 fail
	Barrass 2	-7.54 fail	-29.79 fail	-38.88 fail	-32.18 fail
	Simard	-9.13 fail	-30.26 fail	-38.61 fail	-30.17 fail

E.3 Trends between ship types

		0 - 5	5 - 6	6 - 7	7 +
Chemical Tanker & New Laker	raw	-11.45 fail	-19.83 fail	-33.28 fail	52.32 fail
	area	-10.90 fail	-14.07 fail	-22.44 fail	27.84 fail
	Tuck	-35.82 fail	-64.05 fail	-104.30 fail	0.93 pass
	Barrass 2	2.64 fail	20.33 fail	22.37 fail	20.94 fail
	Simard	-13.68 fail	-17.22 fail	-27.34 fail	17.44 fail

Chemical Tanker & Salty Bulker	raw	29.69 fail	13.84 fail	-19.17 fail	-18.01 fail
	area	25.11 fail	4.93 fail	-12.75 fail	-12.01 fail
	Tuck	6.70 fail	-18.19 fail	-43.45 fail	-15.70 fail
	Barrass 2	18.67 fail	4.65 fail	-7.75 fail	-16.23 fail
	Simard	20.08 fail	0.51 pass	-16.73 fail	-11.16 fail
Chemical Tanker & Salty Laker	raw	12.82 fail	-2.64 fail	-1.81 pass	-49.84 fail
	area	10.36 fail	1.56 pass	11.68 fail	-33.03 fail
	Tuck	-25.26 fail	-44.35 fail	-70.51 fail	-56.39 fail
	Barrass 2	5.01 fail	21.42 fail	51.01 fail	-33.08 fail
	Simard	-0.99 pass	1.14 pass	16.56 fail	-35.75 fail
Chemical Tanker & Trad. Laker	raw	19.62 fail	14.43 fail	-8.34 fail	26.75 fail
	area	16.79 fail	10.01 fail	-3.84 fail	28.23 fail
	Tuck	4.49 fail	-30.38 fail	-78.45 fail	-27.16 fail
	Barrass 2	46.37 fail	26.77 fail	38.10 fail	26.90 fail
	Simard	35.87 fail	10.37 fail	4.15 fail	21.77 fail
New Laker & Salty Bulker	raw	50.68 fail	61.75 fail	7.53 fail	-81.19 fail
	area	45.24 fail	30.18 fail	5.79 fail	-42.48 fail
	Tuck	48.03 fail	59.11 fail	41.64 fail	-8.70 fail
	Barrass 2	14.16 fail	-18.89 fail	-24.15 fail	-28.66 fail
	Simard	33.97 fail	22.63 fail	6.27 fail	-23.75 fail
New Laker & Salty Laker	raw	29.99 fail	26.71 fail	36.16 fail	-98.27 fail
	area	26.84 fail	19.61 fail	31.51 fail	-57.20 fail
	Tuck	12.48 fail	16.38 fail	30.36 fail	-34.85 fail
	Barrass 2	2.17 fail	5.57 fail	25.35 fail	-37.05 fail
	Simard	12.54 fail	18.79 fail	37.26 fail	-36.84 fail
New Laker & Traditional Laker	raw	37.09 fail	62.15 fail	23.02 fail	-32.76 fail
	area	33.54 fail	33.41 fail	14.55 fail	-11.69 fail
	Tuck	44.25 fail	32.97 fail	19.92 fail	-15.41 fail
	Barrass 2	40.25 fail	12.18 fail	13.60 fail	-9.22 fail
	Simard	47.69 fail	29.82 fail	25.88 fail	-7.24 fail
Salty Bulker & Salty Laker	raw	-22.97 fail	-25.22 fail	19.31 fail	-43.79 fail
	area	-20.00 fail	-3.84 fail	21.60 fail	-35.52 fail
	Tuck	-36.83 fail	-33.36 fail	-15.22 fail	-56.23 fail
	Barrass 2	-11.94 fail	19.77 fail	47.23 fail	-25.88 fail
	Simard	-20.77 fail	0.82 pass	27.63 fail	-35.32 fail
Salty Bulker & Traditional Laker	raw	-11.69 fail	1.11 pass	11.52 fail	58.06 fail
	area	-9.50 fail	7.29 fail	7.68 fail	80.18 fail
	Tuck	-2.34 fail	-16.50 fail	-23.20 fail	-19.11 fail
	Barrass 2	33.22 fail	25.78 fail	36.64 fail	56.88 fail
	Simard	20.42 fail	11.52 fail	17.53 fail	45.89 fail
Salty Laker & Traditional Laker	raw	9.57 fail	25.98 fail	-7.56 fail	80.52 fail
	area	8.98 fail	9.78 fail	-13.36 fail	89.66 fail
	Tuck	33.17 fail	14.70 fail	-9.51 fail	38.60 fail
	Barrass 2	38.72 fail	5.64 fail	-11.93 fail	65.70 fail
	Simard	36.27 fail	9.29 fail	-10.21 fail	65.31 fail

F RESULTS OF STATISTICAL ANALYSIS FOR LAKE ST. LOUIS

F.1 Results of statistical analysis for ships passing twice

		0 - 7	7 - 9	9 - 11	11 +
ALS303 & ALS316	raw	-3.46 fail	-6.12 fail	-6.79 fail	-7.94 fail
	area	-4.42 fail	-12.82 fail	-0.38 pass	-17.49 fail
	Tuck	-17.90 fail	-27.94 fail	-21.04 fail	-12.18 fail
	Barrass 2	-14.92 fail	-17.56 fail	-19.74 fail	-12.54 fail
	Simard	-10.80 fail	-18.24 fail	-14.96 fail	-6.97 fail
cni315 & Cni320	raw	27.73 fail	10.63 fail	26.46 fail	n<30
	area	24.52 fail	15.28 fail	21.37 fail	n<30
	Tuck	18.92 fail	18.42 fail	16.70 fail	n<30
	Barrass 2	-1.12 pass	20.24 fail	15.10 fail	n<30
	Simard	8.98 fail	22.54 fail	24.73 fail	n<30
JBA306 & JBA314	raw	13.07 fail	-19.61 fail	9.45 fail	n<30
	area	16.16 fail	-9.14 fail	17.16 fail	n<30
	Tuck	1.81 pass	-3.19 fail	6.31 fail	n<30
	Barrass 2	-8.53 fail	8.25 fail	-1.23 pass	n<30
	Simard	-3.81 fail	2.04 fail	-1.42 pass	n<30
Pma299 & Pma310	raw	-23.79 fail	-8.20 fail	16.63 fail	n<30
	area	-27.05 fail	-20.11 fail	16.23 fail	n<30
	Tuck	-34.02 fail	-16.01 fail	-6.79 fail	n<30
	Barrass 2	-10.98 fail	-11.63 fail	-21.98 fail	n<30
	Simard	-16.95 fail	-13.09 fail	-13.21 fail	n<30

F.2 Results of statistical analysis for ships of the same type

F.2.1 New Lakers

		0 - 7	7 - 9	9 – 11	11 +
Pma299 & Pma310	raw	-23.79 fail	-8.20 fail	16.63 fail	n<30
	area	-27.05 fail	-20.11 fail	16.23 fail	n<30
	Tuck	-34.02 fail	-16.01 fail	-6.79 fail	n<30
	Barrass 2	-10.98 fail	-11.63 fail	-21.98 fail	n<30
	Simard	-16.95 fail	-13.09 fail	-13.21 fail	n<30
Pma299 & Alv316	raw	-9.62 fail	-18.39 fail	-15.78 fail	-25.59 fail
	area	-11.53 fail	-30.11 fail	-22.60 fail	-9.22 fail
	Tuck	-3.04 fail	-29.83 fail	-15.56 fail	0.10 pass
	Barrass 2	7.21 fail	-8.74 fail	-14.78 fail	2.96 fail
	Simard	3.94 fail	-21.43 fail	-18.57 fail	-8.25 fail
Pma299 & Cni315	raw	-19.22 fail	-4.34 fail	11.07 fail	n<30
	area	-19.12 fail	-13.36 fail	1.62 pass	n<30
	Tuck	-7.69 fail	-8.02 fail	5.78 fail	n<30
	Barrass 2	10.16 fail	-9.52 fail	0.06 pass	n<30
	Simard	2.50 fail	-10.52 fail	2.05 fail	n<30

pma299 & cni320	raw	7.16 fail	4.48 fail	32.69 fail	n<30
	area	6.83 fail	5.80 fail	27.32 fail	n<30
	Tuck	17.09 fail	23.75 fail	24.28 fail	n<30
	Barrass 2	17.45 fail	20.30 fail	16.87 fail	n<30
	Simard	21.86 fail	20.32 fail	26.95 fail	n<30
pma310 & alv316	raw	15.94 fail	-15.13 fail	-25.07 fail	n<30
	area	12.69 fail	-14.07 fail	-36.84 fail	n<30
	Tuck	23.24 fail	-16.71 fail	-11.65 fail	n<30
	Barrass 2	14.83 fail	1.43 pass	-0.87 pass	n<30
	Simard	16.99 fail	-9.56 fail	-11.85 fail	n<30
pma310 & cni315	raw	1.79 pass	4.34 fail	-6.79 fail	n<30
	area	6.12 fail	-7.04 fail	-10.55 fail	n<30
	Tuck	16.56 fail	-0.79 pass	11.51 fail	n<30
	Barrass 2	16.38 fail	-3.86 fail	18.44 fail	n<30
	Simard	15.16 fail	-3.24 fail	14.87 fail	n<30
pma310 & cni320	raw	34.70 fail	16.63 fail	20.13 fail	n<30
	area	32.81 fail	29.25 fail	16.71 fail	n<30
	Tuck	53.36 fail	47.27 fail	30.29 fail	n<30
	Barrass 2	20.41 fail	36.49 fail	33.04 fail	n<30
	Simard	29.73 fail	41.36 fail	37.81 fail	n<30
alv316 & cni315	raw	-11.83 fail	16.68 fail	22.20 fail	n<30
	area	-6.42 fail	-1.85 pass	20.87 fail	n<30
	Tuck	-4.21 fail	6.94 fail	18.39 fail	n<30
	Barrass 2	4.55 fail	-4.43 fail	13.69 fail	n<30
	Simard	-0.89 pass	1.65 pass	19.51 fail	n<30
alv316 & cni320	raw	18.95 fail	23.07 fail	33.77 fail	n<30
	area	16.78 fail	37.85 fail	43.49 fail	n<30
	Tuck	15.25 fail	58.80 fail	32.02 fail	n<30
	Barrass 2	5.78 fail	28.93 fail	25.22 fail	n<30
	Simard	8.81 fail	52.45 fail	33.85 fail	n<30
cni315 & cni320	raw	27.73 fail	10.63 fail	26.46 fail	n<30
	area	24.52 fail	15.28 fail	21.37 fail	n<30
	Tuck	18.92 fail	18.42 fail	16.70 fail	n<30
	Barrass 2	-1.12 pass	20.24 fail	15.10 fail	n<30
	Simard	8.98 fail	22.54 fail	24.73 fail	n<30

F.2.2 Traditional Lakers

		0 - 7	7 - 9	9 - 11	11 +
CAV305 & HAL308	raw	33.86 fail	-9.63 fail	6.17 fail	22.57 fail
	area	32.83 fail	-10.00 fail	10.55 fail	11.44 fail
	Tuck	18.18 fail	-19.12 fail	4.42 fail	8.30 fail
	Barrass 2	-5.34 fail	-6.42 fail	6.53 fail	10.77 fail
	Simard	-2.06 fail	-11.15 fail	8.13 fail	19.39 fail

CAV305 & MAN301	raw	25.42 fail	2.40 fail	30.27 fail	54.97 fail
	area	23.18 fail	12.26 fail	34.56 fail	55.81 fail
	Tuck	39.45 fail	15.31 fail	33.58 fail	52.70 fail
	Barrass 2	29.82 fail	19.85 fail	21.80 fail	56.94 fail
	Simard	31.16 fail	24.28 fail	35.03 fail	70.27 fail
HAL308 & MAN301	raw	6.35 fail	12.62 fail	30.42 fail	40.01 fail
	area	5.77 fail	25.76 fail	32.16 fail	56.28 fail
	Tuck	29.53 fail	29.69 fail	29.23 fail	59.02 fail
	Barrass 2	33.46 fail	25.27 fail	16.39 fail	57.00 fail
	Simard	33.37 fail	28.06 fail	27.25 fail	73.05 fail

F.2.3 Chemical Tankers

		0 - 7	7 - 9	9 - 11	11 +
ALS303 & ALS316	raw	-3.46 fail	-6.12 fail	-6.79 fail	-7.94 fail
	area	-4.42 fail	-12.82 fail	-0.38 pass	-17.49 fail
	Tuck	-17.90 fail	-27.94 fail	-21.04 fail	-12.18 fail
	Barrass 2	-14.92 fail	-17.56 fail	-19.74 fail	-12.54 fail
	Simard	-10.80 fail	-18.24 fail	-14.96 fail	-6.97 fail
ALS303 & TUK317	raw	24.56 fail	-0.83 pass	-1.84 pass	11.60 fail
	area	-2.39 fail	-2.89 fail	9.17 fail	5.25 fail
	Tuck	-13.73 fail	-20.04 fail	9.74 fail	-14.37 fail
	Barrass 2	-10.25 fail	1.70 pass	41.18 fail	27.36 fail
	Simard	-5.44 fail	-4.06 fail	7.86 fail	9.14 fail
ALS316 & TUK317	raw	20.23 fail	5.11 fail	10.30 fail	20.05 fail
	area	3.12 fail	5.77 fail	14.48 fail	16.19 fail
	Tuck	5.48 fail	0.13 pass	38.69 fail	-5.31 fail
	Barrass 2	3.44 fail	10.32 fail	68.35 fail	37.73 fail
	Simard	4.67 fail	7.71 fail	33.84 fail	16.20 fail

F.2.4 Salty Lakers

		0 - 7	7 - 9	9 - 11	11 +
ATE313 & FEF298	raw	-17.07 fail	-16.11 fail	-17.62 fail	-26.39 fail
	area	-25.85 fail	-16.04 fail	-18.91 fail	-30.25 fail
	Tuck	0.20 pass	-10.81 fail	-17.20 fail	12.18 fail
	Barrass 2	4.72 fail	-10.61 fail	-33.54 fail	-16.44 fail
	Simard	7.22 fail	-12.91 fail	-24.92 fail	-11.82 fail
ATE313 & FSA301	raw	-27.12 fail	-6.76 fail	-10.49 fail	-13.56 fail
	area	-31.53 fail	-12.55 fail	-17.76 fail	-31.54 fail
	Tuck	-15.42 fail	-8.99 fail	-25.38 fail	11.09 fail
	Barrass 2	-5.75 fail	-13.72 fail	-37.02 fail	0.09 pass
	Simard	-4.45 fail	-9.56 fail	-21.64 fail	6.59 fail

ATE313 & JBA306	raw	-36.61 fail	-14.08 fail	20.24 fail	n<30
	area	-29.05 fail	-6.37 fail	11.73 fail	n<30
	Tuck	8.28 fail	2.53 fail	-5.17 fail	n<30
	Barrass 2	37.78 fail	6.99 fail	-13.00 fail	n<30
	Simard	28.67 fail	-0.83 pass	-0.13 pass	n<30
ATE313 & JBA314	raw	-4.18 fail	-28.73 fail	29.39 fail	n<30
	area	-4.38 fail	-11.25 fail	25.24 fail	n<30
	Tuck	10.25 fail	-0.57 pass	-0.55 pass	n<30
	Barrass 2	21.96 fail	16.84 fail	-15.36 fail	n<30
	Simard	19.85 fail	0.98 pass	-1.09 pass	n<30
FEF298 & FSA301	raw	-12.15 fail	0.05 pass	3.46 fail	18.12 fail
	area	-10.26 fail	-6.37 fail	-2.63 fail	0.40 pass
	Tuck	-16.43 fail	-4.66 fail	-11.95 fail	-0.23 pass
	Barrass 2	-10.39 fail	-7.81 fail	-2.72 fail	19.19 fail
	Simard	-10.74 fail	-4.02 fail	-1.71 pass	19.93 fail
FEF298 & JBA306	raw	-24.88 fail	10.19 fail	27.54 fail	n<30
	area	-8.63 fail	15.28 fail	26.99 fail	n<30
	Tuck	8.37 fail	11.84 fail	15.18 fail	n<30
	Barrass 2	36.39 fail	16.03 fail	25.65 fail	n<30
	Simard	24.81 fail	12.67 fail	27.34 fail	n<30
FEF298 & JBA314	raw	1.17 pass	2.76 fail	31.07 fail	n<30
	area	10.50 fail	10.89 fail	34.67 fail	n<30
	Tuck	10.37 fail	10.77 fail	19.64 fail	n<30
	Barrass 2	20.16 fail	25.12 fail	26.42 fail	n<30
	Simard	16.24 fail	14.24 fail	26.98 fail	n<30
FSA301 & JBA306	raw	-14.26 fail	4.09 fail	18.42 fail	n<30
	area	1.27 pass	10.75 fail	23.63 fail	n<30
	Tuck	17.50 fail	9.50 fail	24.08 fail	n<30
	Barrass 2	40.01 fail	16.87 fail	29.33 fail	n<30
	Simard	29.74 fail	9.38 fail	22.86 fail	n<30
FSA301 & JBA314	raw	5.93 fail	1.08 pass	21.14 fail	n<30
	area	17.51 fail	9.26 fail	29.23 fail	n<30
	Tuck	19.04 fail	8.91 fail	27.20 fail	n<30
	Barrass 2	24.63 fail	21.36 fail	30.36 fail	n<30
	Simard	21.60 fail	9.87 fail	22.52 fail	n<30
JBA306 & JBA314	raw	13.07 fail	-19.61 fail	9.45 fail	n<30
	area	16.16 fail	-9.14 fail	17.16 fail	n<30
	Tuck	1.81 pass	-3.19 fail	6.31 fail	n<30
	Barrass 2	-8.53 fail	8.25 fail	-1.23 pass	n<30
	Simard	-3.81 fail	2.04 fail	-1.42 pass	n<30

F.2.5 Salty Bulkers

		0 - 7	7 - 9	9 - 11	11 +
blr304 & cle307	raw	-2.54 fail	1.36 pass	-25.65 fail	n<30
	area	-10.62 fail	-6.59 fail	-22.89 fail	n<30
	Tuck	0.43 pass	-7.80 fail	5.87 fail	n<30
	Barrass 2	-3.25 fail	-8.76 fail	1.17 pass	n<30
	Simard	1.37 pass	-4.95 fail	-6.55 fail	n<30
blr304 & fos304	raw	6.02 fail	-3.83 fail	-45.85 fail	n<30
	area	16.28 fail	-9.16 fail	-49.81 fail	n<30
	Tuck	-0.44 pass	-12.85 fail	-23.12 fail	n<30
	Barrass 2	-9.66 fail	-22.61 fail	-32.71 fail	n<30
	Simard	-10.53 fail	-12.36 fail	-38.57 fail	n<30
blr304 & lac315	raw	-4.13 fail	19.98 fail	-31.28 fail	n<30
	area	8.48 fail	0.71 pass	-16.23 fail	n<30
	Tuck	1.16 pass	-12.74 fail	20.10 fail	n<30
	Barrass 2	5.21 fail	-5.60 fail	34.09 fail	n<30
	Simard	0.86 pass	-0.13 pass	13.38 fail	n<30
blr304 & mar297	raw	14.69 fail	-1.66 pass	-33.44 fail	n<30
	area	29.44 fail	2.39 fail	-18.34 fail	n<30
	Tuck	18.90 fail	-8.06 fail	3.04 fail	n<30
	Barrass 2	11.52 fail	-9.05 fail	9.57 fail	n<30
	Simard	7.70 fail	-10.72 fail	-5.55 fail	n<30
blr304 & Mir311	raw	n<30	n<30	-37.19 fail	n<30
	area	n<30	n<30	-22.25 fail	n<30
	Tuck	n<30	n<30	-7.02 fail	n<30
	Barrass 2	n<30	n<30	9.41 fail	n<30
	Simard	n<30	n<30	-6.85 fail	n<30
blr304 & Zos302	raw	23.05 fail	-4.33 fail	-45.32 fail	n<30
	area	30.08 fail	-16.04 fail	-48.97 fail	n<30
	Tuck	13.45 fail	-18.38 fail	-26.00 fail	n<30
	Barrass 2	7.12 fail	-20.69 fail	-15.91 fail	n<30
	Simard	7.12 fail	-12.36 fail	-27.14 fail	n<30
Cle307 & Fos304	raw	6.34 fail	-3.91 fail	-26.23 fail	-60.37 fail
	area	18.55 fail	-0.61 pass	-28.54 fail	-62.85 fail
	Tuck	-0.72 pass	-4.87 fail	-30.62 fail	-40.19 fail
	Barrass 2	-5.37 fail	-5.13 fail	-35.71 fail	-45.80 fail
	Simard	-10.23 fail	-6.46 fail	-37.72 fail	-54.28 fail
cle307 & lac315	raw	-1.56 pass	5.29 fail	6.50 fail	43.82 fail
	area	14.61 fail	6.24 fail	15.04 fail	60.46 fail
	Tuck	0.71 pass	0.86 pass	13.74 fail	2.07 fail
	Barrass 2	7.06 fail	4.39 fail	36.06 fail	30.89 fail
	Simard	-0.28 pass	4.64 fail	29.19 fail	28.22 fail

cle307 & mar297	raw	11.83 fail	-1.92 pass	4.15 fail	n<30
	area	23.09 fail	7.18 fail	12.42 fail	n<30
	Tuck	14.23 fail	1.42 pass	-4.43 fail	n<30
	Barrass 2	12.45 fail	4.94 fail	9.03 fail	n<30
	Simard	4.70 fail	-0.37 pass	2.11 fail	n<30
cle307 & mir311	raw	n<30	n<30	-10.75 fail	-6.51 fail
	area	n<30	n<30	-1.80 pass	34.66 fail
	Tuck	n<30	n<30	-12.27 fail	-18.74 fail
	Barrass 2	n<30	n<30	8.82 fail	32.95 fail
	Simard	n<30	n<30	-1.95 pass	11.67 fail
cle307 & zos302	raw	17.71 fail	-4.31 fail	-15.69 fail	-6.32 fail
	area	25.56 fail	-4.90 fail	-21.32 fail	-0.03 pass
	Tuck	10.71 fail	-10.29 fail	-34.97 fail	-51.90 fail
	Barrass 2	8.91 fail	-5.31 fail	-18.84 fail	-22.54 fail
	Simard	4.83 fail	-6.55 fail	-26.04 fail	-28.29 fail
fos304 & lac315	raw	-7.44 fail	8.83 fail	34.25 fail	85.91 fail
	area	-5.32 fail	8.19 fail	51.44 fail	105.03 fail
	Tuck	1.33 pass	6.63 fail	54.67 fail	28.49 fail
	Barrass 2	11.74 fail	12.53 fail	73.20 fail	59.43 fail
	Simard	8.86 fail	11.87 fail	55.34 fail	70.23 fail
fos304 & mar297	raw	7.13 fail	3.22 fail	32.61 fail	n<30
	area	6.88 fail	9.67 fail	48.62 fail	n<30
	Tuck	14.48 fail	6.67 fail	34.52 fail	n<30
	Barrass 2	18.98 fail	15.48 fail	50.46 fail	n<30
	Simard	16.67 fail	7.52 fail	40.64 fail	n<30
fos304 & mir311	raw	n<30	n<30	17.90 fail	49.85 fail
	area	n<30	n<30	23.90 fail	91.57 fail
	Tuck	n<30	n<30	12.24 fail	18.69 fail
	Barrass 2	n<30	n<30	40.21 fail	65.72 fail
	Simard	n<30	n<30	30.91 fail	57.20 fail
fos304 & zos302	raw	14.92 fail	-0.36 pass	15.43 fail	50.43 fail
	area	12.11 fail	-4.87 fail	15.26 fail	61.47 fail
	Tuck	11.11 fail	-5.42 fail	0.19 pass	-3.00 fail
	Barrass 2	14.97 fail	-0.49 pass	23.69 fail	29.18 fail
	Simard	15.27 fail	-0.13 pass	20.69 fail	35.45 fail
Lac315 & mar297	raw	12.29 fail	-15.64 fail	-4.79 fail	n<30
	area	12.16 fail	0.76 pass	-6.02 fail	n<30
	Tuck	11.16 fail	0.91 pass	-28.31 fail	n<30
	Barrass 2	2.44 fail	0.07 pass	-40.62 fail	n<30
	Simard	4.32 fail	-8.85 fail	-34.12 fail	n<30

Lac315 & mir311	raw	n<30	N<30	-20.44 fail	-43.05 fail
	area	n<30	N<30	-14.59 fail	-33.20 fail
	Tuck	n<30	N<30	-24.54 fail	-14.39 fail
	Barrass 2	n<30	N<30	-19.79 fail	-4.43 fail
	Simard	n<30	N<30	-20.41 fail	-14.06 fail
Lac315 & zos302	raw	17.55 fail	-9.32 fail	-28.81 fail	-43.28 fail
	area	16.29 fail	-13.99 fail	-68.75 fail	-59.54 fail
	Tuck	8.54 fail	-12.68 fail	-70.99 fail	-32.72 fail
	Barrass 2	-0.04 pass	-12.19 fail	-71.60 fail	-44.25 fail
	Simard	4.55 fail	-11.89 fail	-57.90 fail	-51.49 fail
mar297 & mir311	raw	n<30	N<30	-18.00 fail	n<30
	area	n<30	N<30	-12.47 fail	n<30
	Tuck	n<30	N<30	-10.76 fail	n<30
	Barrass 2	n<30	N<30	2.95 fail	n<30
	Simard	n<30	N<30	-3.46 fail	n<30
mar297 & Zos302	raw	8.48 fail	-3.71 fail	-25.90 fail	n<30
	area	7.75 fail	-16.16 fail	-61.63 fail	n<30
	Tuck	-2.41 fail	-12.37 fail	-44.14 fail	n<30
	Barrass 2	-3.39 fail	-14.59 fail	-38.22 fail	n<30
	Simard	0.92 pass	-7.60 fail	-31.37 fail	n<30
mir311 & Zos302	raw	n<30	N<30	-4.15 fail	0.25 pass
	area	n<30	N<30	-15.77 fail	-33.78 fail
	Tuck	n<30	N<30	-13.20 fail	-24.40 fail
	Barrass 2	n<30	N<30	-25.80 fail	-50.00 fail
	Simard	n<30	N<30	-17.02 fail	-34.37 fail

F.3 Trends between ship types

		0 – 7	7 - 9	9 - 11	11 +
Chem. Tanker & New Laker	raw	14.68 fail	6.97 fail	39.19 fail	15.24 fail
	area	18.61 fail	20.69 fail	42.77 fail	28.76 fail
	Tuck	-8.55 fail	-11.25 fail	-18.74 fail	-36.75 fail
	Barrass 2	20.14 fail	41.06 fail	56.43 fail	59.40 fail
	Simard	9.37 fail	19.00 fail	40.54 fail	18.98 fail
Chem. Tanker & Salty Bulker	raw	40.70 fail	8.34 fail	0.94 pass	-14.20 fail
	area	40.52 fail	20.94 fail	9.57 fail	-11.70 fail
	Tuck	12.84 fail	5.96 fail	-3.61 fail	-14.05 fail
	Barrass 2	13.22 fail	22.63 fail	12.62 fail	12.99 fail
	Simard	18.55 fail	22.26 fail	11.32 fail	-0.85 pass

Chem. Tanker & Salty Laker	raw	45.95 fail	19.82 fail	41.07 fail	10.46 fail
	area	47.65 fail	28.82 fail	51.06 fail	22.41 fail
	Tuck	-1.67 pass	2.67 fail	-8.80 fail	-10.88 fail
	Barrass 2	0.81 pass	36.56 fail	53.13 fail	73.39 fail
	Simard	1.09 pass	35.90 fail	50.63 fail	41.70 fail
Chem. Tanker & Trad. Laker	raw	51.75 fail	22.56 fail	33.05 fail	57.03 fail
	area	49.93 fail	35.92 fail	48.27 fail	94.54 fail
	Tuck	7.92 fail	4.29 fail	1.38 pass	16.13 fail
	Barrass 2	11.76 fail	36.12 fail	56.39 fail	100.95 fail
	Simard	15.03 fail	33.21 fail	46.83 fail	72.09 fail
New Laker & Salty Bulker	raw	20.01 fail	3.03 fail	-38.11 fail	-27.00 fail
	area	15.48 fail	0.50 pass	-33.36 fail	-34.50 fail
	Tuck	24.85 fail	27.96 fail	16.31 fail	24.55 fail
	Barrass 2	-11.56 fail	-27.33 fail	-50.37 fail	-44.95 fail
	Simard	7.99 fail	6.05 fail	-25.60 fail	-17.92 fail
New Laker & Salty Laker	raw	24.87 fail	20.48 fail	6.71 fail	-6.49 fail
	area	22.41 fail	15.35 fail	13.73 fail	-9.80 fail
	Tuck	9.56 fail	18.97 fail	14.89 fail	26.44 fail
	Barrass 2	-22.46 fail	4.96 fail	-4.22 fail	-2.96 fail
	Simard	-10.18 fail	24.71 fail	16.77 fail	15.08 fail
New Laker & Trad. Laker	raw	31.21 fail	23.03 fail	3.76 fail	33.52 fail
	area	27.04 fail	26.06 fail	19.38 fail	50.59 fail
	Tuck	19.49 fail	16.30 fail	18.35 fail	42.03 fail
	Barrass 2	-12.89 fail	10.39 fail	14.18 fail	36.08 fail
	Simard	4.33 fail	23.77 fail	21.31 fail	46.61 fail
Salty Bulker & Salty Laker	raw	10.26 fail	16.17 fail	40.07 fail	24.24 fail
	area	12.36 fail	14.93 fail	42.46 fail	29.37 fail
	Tuck	-24.14 fail	-3.97 fail	-5.16 fail	2.65 fail
	Barrass 2	-15.96 fail	23.19 fail	46.36 fail	52.15 fail
	Simard	-23.08 fail	18.47 fail	35.77 fail	37.09 fail
Salty Bulker & Trad. Laker	raw	22.93 fail	19.48 fail	32.19 fail	67.42 fail
	area	19.69 fail	25.74 fail	41.18 fail	89.31 fail
	Tuck	-7.61 fail	-0.47 pass	4.77 fail	25.00 fail
	Barrass 2	-1.98 fail	24.51 fail	49.96 fail	84.07 fail
	Simard	-4.67 fail	19.63 fail	36.06 fail	66.38 fail
Salty Laker & Trad. Laker	raw	14.47 fail	5.27 fail	-0.98 pass	47.84 fail
	area	10.08 fail	13.03 fail	9.68 fail	69.83 fail
	Tuck	15.71 fail	2.34 fail	9.49 fail	22.74 fail
	Barrass 2	14.05 fail	5.66 fail	16.75 fail	44.70 fail
	Simard	18.39 fail	5.79 fail	11.67 fail	38.55 fail

G RESULTS OF STATISTICAL ANALYSIS FOR LAKE ST. FRANCIS

G.1 Trends between ship types

		0 – 8	8 - 9	9 - 10	10 +
ATE313 (SL)	raw	-7.82 fail	-27.56 fail	-70.54 fail	-48.85 fail
&	area	-6.04 fail	-19.06 fail	-74.48 fail	-60.53 fail
HAL308 (TL)	Tuck	-8.51 fail	-30.75 fail	-90.72 fail	-70.56 fail
	Barrass 2	-8.74 fail	-30.60 fail	-85.19 fail	-74.78 fail
	Simard	-8.13 fail	-30.94 fail	-84.64 fail	-66.02 fail
ATE313 (SL)	raw	5.24 fail	7.00 fail	21.42 fail	13.23 fail
&	area	5.58 fail	15.97 fail	29.99 fail	8.13 fail
LAC315 (SB)	Tuck	10.13 fail	28.09 fail	63.68 fail	80.65 fail
	Barrass 2	5.63 fail	2.92 fail	13.29 fail	0.93 pass
	Simard	7.45 fail	12.55 fail	35.59 fail	40.47 fail
ATE313 (SL)	raw	-5.22 fail	5.33 fail	n<30	n<30
&	area	-0.56 pass	-9.62 fail	n<30	n<30
PMA310 (NL)	Tuck	-3.50 fail	-1.82 pass	n<30	n<30
	Barrass 2	-7.05 fail	-18.25 fail	n<30	n<30
	Simard	-8.05 fail	-15.14 fail	n<30	n<30
HAL308 (TL)	raw	14.45 fail	38.51 fail	84.94 fail	55.26 fail
&	area	13.45 fail	33.73 fail	98.75 fail	60.14 fail
LAC315 (SB)	Tuck	22.59 fail	55.90 fail	140.02 fail	98.31 fail
	Barrass 2	17.38 fail	35.13 fail	91.49 fail	73.55 fail
	Simard	18.87 fail	43.76 fail	110.15 fail	79.45 fail
HAL308 (TL)	raw	9.20 fail	40.65 fail	n<30	n<30
&	area	12.31 fail	7.89 fail	n<30	n<30
PMA310 (NL)	Tuck	19.97 fail	31.39 fail	n<30	n<30
	Barrass 2	6.04 fail	14.53 fail	n<30	n<30
	Simard	0.69 pass	21.17 fail	n<30	n<30
LAC315 (SB)	raw	-12.13 fail	-3.49 fail	n<30	n<30
&	area	-8.51 fail	-22.74 fail	n<30	n<30
PMA310 (NL)	Tuck	-17.71 fail	-33.93 fail	n<30	n<30
	Barrass 2	-15.73 fail	-22.78 fail	n<30	n<30
	Simard	-18.92 fail	-31.80 fail	n<30	n<30

(SL): Salty Laker, (TL): Traditional Laker, (SB): Salty Bulker, (NL): New Laker

H RESULTS OF STATISTICAL ANALYSIS FOR WILEY-DONDERO CANAL

H.1 Trends between ship types

		0 - 6	6 - 8	8 - 10	10 +
ATE313 (SL)	raw	7.37 fail	-5.23 fail	-5.93 fail	-15.80 fail
&	area	6.54 fail	-8.96 fail	-10.18 fail	-15.51 fail
HAL308 (TL)	Tuck	6.56 fail	-11.69 fail	-13.80 fail	-3.75 fail
	Barrass 2	6.37 fail	-8.77 fail	-11.67 fail	-6.15 fail
	Simard	6.70 fail	-9.01 fail	-8.83 fail	-11.36 fail
ATE313 (SL)	raw	14.48 fail	-15.51 fail	5.43 fail	-10.27 fail
&	area	14.34 fail	-14.92 fail	-2.49 fail	-10.77 fail
LAC315 (SB)	Tuck	16.45 fail	-9.98 fail	-1.37 pass	3.36 fail
	Barrass 2	14.43 fail	-19.67 fail	-15.60 fail	-10.64 fail
	Simard	15.05 fail	-19.33 fail	-5.33 fail	-9.71 fail
ATE313 (SL)	raw	20.06 fail	-7.10 fail	32.22 fail	n<30
&	area	18.93 fail	-10.31 fail	4.86 fail	n<30
PMA310 (NL)	Tuck	16.42 fail	0.31 pass	-2.90 fail	n<30
	Barrass 2	14.93 fail	-2.31 fail	-4.00 fail	n<30
	Simard	15.88 fail	-5.09 fail	3.48 fail	n<30
HAL308 (TL)	raw	8.23 fail	-12.49 fail	11.72 fail	2.57 fail
&	area	8.68 fail	-10.33 fail	8.30 fail	4.60 fail
LAC315 (SB)	Tuck	10.92 fail	-1.54 pass	12.01 fail	6.90 fail
	Barrass 2	8.25 fail	-19.67 fail	-4.37 fail	-4.30 fail
	Simard	8.75 fail	-16.76 fail	3.97 fail	0.74 pass
HAL308 (TL)	raw	16.11 fail	-1.93 pass	45.47 fail	n<30
&	area	14.76 fail	-1.88 pass	11.01 fail	n<30
PMA310 (NL)	Tuck	10.73 fail	17.33 fail	5.28 fail	n<30
	Barrass 2	8.67 fail	9.56 fail	4.26 fail	n<30
	Simard	9.61 fail	4.05 fail	12.48 fail	n<30
LAC315 (SB)	raw	15.65 fail	11.36 fail	24.50 fail	n<30
&	area	11.97 fail	9.16 fail	6.44 fail	n<30
PMA310 (NL)	Tuck	-2.11 fail	12.24 fail	-2.01 fail	n<30
	Barrass 2	-0.19 pass	23.00 fail	7.14 fail	n<30
	Simard	0.66 pass	17.03 fail	9.06 fail	n<30

(SL): Salty Laker, (TL): Traditional Laker, (SB): Salty Bulker, (NL): New Laker

I LIST OF NEGATIVE UKC LOCATIONS BETWEEN ST. LAMBERT AND BEAUHARNOIS

List of all negative UKC locations between St-Lambert and Beauharnois locks

Note: All points match high bottom elevations					**MTM coordinates**	
Ship type	**Ship ID**	**Direction**	**UKC (m)**	**Bottom Elev. (m)**	**North**	**East**
SB	MAR279	Down bound	-0.16	3.25	**5037986.497**	**303863.2683**
SB	LAC315	Up bound	-0.08	2.82	**5037921.88**	**303867.8061**
SB	LAC315	Up bound	-0.04	2.75	**5037833.704**	**303910.8947**
SB	FOSS304	Up bound	-0.24	3.38	**5037685.061**	**303970.995**
SB	LAC315	Up bound	-0.12	2.73	**5037490.084**	**304059.5595**
SB	MAR297	Down bound	-0.33	3.16	**5037175.634**	**304194.7822**
TL	CAV305	Up bound	-0.12	3.16	**5037175.072**	**304196.4523**
SB	FOSS304	Up bound	-0.09	3.02	**5037100.429**	**304229.5698**
SB	LAC315	Up bound	-0.09	2.68	**5034829.491**	**304669.5859**
SB	LAC315	Up bound	-0.01	2.62	**5034809.337**	**304670.5402**
SB	LAC315	Up bound	-0.10	2.67	**5034499.107**	**304680.0719**
SB	LAC315	Up bound	-0.12	2.73	**5034447.301**	**304682.6864**
SB	LAC315	Up bound	-0.14	2.71	**5034424.888**	**304683.9289**
SB	LAC315	Up bound	-0.12	2.74	**5034394.873**	**304685.6698**
SB	LAC315	Up bound	-0.05	2.63	**5034349.513**	**304688.3648**
SB	LAC315	Up bound	-0.05	2.64	**5034249.846**	**304692.5075**
SB	LAC315	Up bound	-0.01	2.64	**5034226.669**	**304693.2151**
SB	LAC315	Up bound	-0.07	2.63	**5034111.049**	**304702.5329**
SB	LAC315	Up bound	-0.31	2.78	**5033843.716**	**304698.5753**
SB	LAC315	Up bound	-0.26	2.62	**5033702.928**	**304708.3848**
SB	LAC315	Up bound	-0.32	2.82	**5033506.432**	**304702.2496**
SB	LAC315	Up bound	-0.55	2.11	**5032622.175**	**304731.604**
TL	HAL308	Up bound	-0.09	3.22	**5032013.195**	**304615.7977**
TL	HAL308	Up bound	-0.22	3.33	**5031986.757**	**304608.5228**
SB	LAC315	Up bound	-0.27	2.79	**5031551.622**	**304457.9769**
SB	LAC315	Up bound	-0.17	2.37	**5031239.925**	**304294.0612**
SB	LAC315	Up bound	-0.14	2.74	**5030204.104**	**303236.7873**
SB	BLR304	Down bound	-0.01	2.82	**5029770.84**	**301459.5492**
SB	FOSS304	Up bound	-0.27	12.19	**5029771.699**	**297600.0748**
SB	LAC315	Up bound	-0.20	12.26	**5029771.757**	**297593.7973**
SL	FEF298	Up bound	-0.25	12.17	**5029711.634**	**297378.9882**
SB	FOSS304	Up bound	-0.25	12.27	**5029712.581**	**297381.0611**
SL	JBA314	Up bound	-0.10	12.19	**5029701.615**	**297345.3851**
SB	FOSS304	Up bound	-0.03	12.04	**5029705.959**	**297340.7456**
SL	JBA314	Up bound	-0.02	12.12	**5029695.982**	**297321.0141**
SL	FEF298	Up bound	-0.32	12.11	**5029702.088**	**297308.5648**
SB	MAR297	Down bound	-0.13	11.83	**5029691.532**	**297286.0597**
SB	LAC315	Up bound	-0.18	12.27	**5029706.045**	**297281.4597**
SL	FEF298	Up bound	-0.16	12.12	**5029681.906**	**297248.1379**
SL	JBA314	Up bound	-0.06	12.21	**5029682.123**	**297260.0859**
SL	JBA314	Up bound	-0.08	12.20	**5029679.449**	**297247.9521**
SL	JBA314	Up bound	-0.11	12.18	**5029672.741**	**297217.6671**
SL	FEF298	Up bound	-0.19	12.18	**5029674.083**	**297217.0219**
SL	FEF298	Up bound	-0.14	12.11	**5029664.497**	**297178.0205**

Negative UKC locations between St-Lambert and Beauharnois locks

Note: All points match high bottom elevations					**MTM coordinates**	
Ship type	**Ship ID**	**Direction**	**UKC (m)**	**Bottom Elev. (m)**	**North**	**East**
SL	FEF298	Up bound	-0.17	12.15	**5029654.828**	**297139.2076**
SB	LAC315	Up bound	-0.07	12.02	**5029669.06**	**297089.6596**
SL	FEF298	Up bound	-0.06	12.04	**5029636.51**	**297070.0462**
SL	FEF298	Up bound	-0.04	12.04	**5029626.369**	**297031.5718**
SL	JBA314	Up bound	-0.04	12.09	**5029625.788**	**297021.5325**
SL	FEF298	Up bound	-0.11	12.11	**5029614.58**	**296985.5591**
SL	JBA314	Up bound	-0.01	12.12	**5029612.68**	**296969.5051**
SL	FEF298	Up bound	-0.07	12.13	**5029611.895**	**296953.7684**
SB	LAC315	Up bound	-0.35	12.32	**5029624.835**	**296890.623**
CT	TUK317	Up bound	0.00	12.84	**5029527.645**	**296573.6886**
NL	CNI315	Down bound	-0.47	12.84	**5029527.764**	**296573.2307**
SL	FEF298	Up bound	-0.79	12.87	**5029526.723**	**296571.6207**
NL	PMA299	Up bound	-0.23	12.08	**5029368.597**	**295998.8884**
SB	LAC315	Up bound	-0.45	11.80	**5029119.594**	**294378.053**
SB	LAC315	Up bound	-0.44	11.85	**5029116.188**	**294346.4556**
CT	ALS316	Down bound	-0.13	12.68	**5030496.256**	**291567.7611**
TL	MAN301	Down bound	-0.02	12.68	**5030500.459**	**291569.4895**
CT	ALS316	Down bound	-0.35	12.92	**5030507.326**	**291550.2536**
SL	FSA301	Up bound	-0.06	11.58	**5030511.555**	**291552.3917**
SL	FSA301	Up bound	-0.05	11.56	**5030522.303**	**291531.1061**
CT	ALS316	Down bound	-0.17	12.77	**5030532.713**	**291509.3455**
SL	FSA301	Up bound	-1.01	12.58	**5030532.844**	**291509.7304**
SL	FSA301	Up bound	-0.49	12.04	**5030550.553**	**291474.2663**
SL	FSA301	Up bound	-0.18	11.62	**5030582.682**	**291410.7219**
SL	FSA301	Up bound	-0.32	11.78	**5030593.618**	**291389.8964**
SL	FSA301	Up bound	-0.46	11.98	**5030614.73**	**291348.284**
NL	CNI320	Up bound	-0.50	12.69	**5030759.537**	**290954.6631**
SL	FEF298	Up bound	-0.74	12.69	**5030759.693**	**290954.1211**
SL	FSA301	Up bound	-0.07	11.37	**5030601.297**	**289514.7599**
SL	FSA301	Up bound	-0.02	11.31	**5030574.13**	**289500.7613**
SL	FSA301	Up bound	-0.17	11.43	**5030576.138**	**289465.8356**
SL	FSA301	Up bound	-0.06	11.37	**5030563.207**	**289420.0803**
SL	FSA301	Up bound	-0.04	11.34	**5030539.035**	**289413.2502**
SL	FSA301	Up bound	-0.01	11.30	**5030547.063**	**289392.648**
SB	LAC315	Up bound	-0.09	11.47	**5030517.521**	**289367.4632**
SL	FSA301	Up bound	-0.22	11.49	**5030516.644**	**289301.911**
SB	LAC315	Up bound	-0.02	11.45	**5030512.114**	**289354.3378**
SB	LAC315	Up bound	-0.04	11.49	**5030504.059**	**289334.6208**
SB	LAC315	Up bound	-0.04	11.49	**5030495.973**	**289314.9431**
SL	FSA301	Up bound	-0.31	11.47	**5030412.933**	**289039.836**
SB	LAC315	Up bound	-0.02	11.55	**5030396.663**	**289054.5025**
SL	FSA301	Up bound	-0.31	11.48	**5030273.734**	**288755.4944**
NL	CNI320	Up bound	-0.07	12.42	**5029672.399**	**287109.784**
SB	MAR297	Down bound	-0.59	13.30	**5020491.21**	**272368.6248**
SB	MAR297	Down bound	-0.60	13.34	**5020476.035**	**272361.2721**

Negative UKC locations between St-Lambert and Beauharnois locks

Note: All points match high bottom elevations					MTM coordinates	
Ship type	**Ship ID**	**Direction**	**UKC (m)**	**Bottom Elev. (m)**	**North**	**East**
SB	MAR297	Down bound	-0.55	13.21	5020465.726	272356.1982
SB	MAR297	Down bound	-0.26	13.09	5020458.322	272351.9387
SB	MAR297	Down bound	-0.09	12.74	5020440.802	272342.4088
SB	MAR297	Down bound	-0.02	12.67	5020415.836	272328.2585
SB	LAC315	Up bound	-1.69	13.89	5020344.728	272311.8114
SB	MAR297	Down bound	-1.32	14.00	5020346.941	272288.9007
SB	LAC315	Up bound	-1.95	14.12	5020335.426	272306.8763
SB	LAC315	Up bound	-1.89	14.07	5020308.141	272292.0926
SB	LAC315	Up bound	-1.96	14.07	5020299.337	272287.2569
SB	LAC315	Up bound	-2.02	14.18	5020293.563	272284.1181
SB	LAC315	Up bound	-2.01	14.20	5020279.66	272276.4564
SB	LAC315	Up bound	-2.05	14.22	5020274.353	272273.5364
SB	LAC315	Up bound	-1.85	14.07	5020264.262	272267.9864
SB	LAC315	Up bound	-1.69	13.91	5020257.133	272264.0221
SB	LAC315	Up bound	-1.69	13.91	5020254.815	272262.7685
SB	LAC315	Up bound	-1.53	13.72	5020250.33	272260.264
SB	LAC315	Up bound	-1.55	13.77	5020229.865	272248.869
SB	LAC315	Up bound	-1.91	14.16	5020217.243	272241.7013
NL	PMA299	Up bound	-1.63	14.16	5020217.309	272239.7817
SB	LAC315	Up bound	-2.39	14.62	5020206.809	272235.7847
SB	LAC315	Up bound	-2.38	14.69	5020199.69	272231.8507
SB	LAC315	Up bound	-2.34	14.65	5020194.056	272228.6946
SB	LAC315	Up bound	-2.38	14.62	5020186.225	272224.2771
NL	PMA299	Up bound	-0.91	13.52	5020182.268	272219.4195
SB	MAR297	Down bound	-0.66	13.52	5020191.029	272199.8948
SB	LAC315	Up bound	-2.12	14.37	5020168.019	272213.8673
SB	LAC315	Up bound	-0.11	12.32	5020144.663	272200.6612