IALA Recommendation
O-134

on the

IALA Risk Management Tool
for
Ports and Restricted
Waterways

Edition 2

May 2009
Edition 1.1 / May 2008
Edition 1 / December 2005

Document Revisions

Revisions to the IALA Document are to be noted in the table prior to the issue of a revised document.

Date	Page / Section Revised	Requirement for Revision
May 2008	Whole document	Review in light of developing practice
May 2009	Whole document	Review following release of IWRAP Mk II

IALA Recommendation on IALA Risk Management Tool for Ports and Restricted Waterways

(Recommendation O-134)

THE COUNCIL:

RECALLING that one of the aims of the Association is to foster safe, economic and efficient movement of vessels and the protection of the environment through the improvement and harmonisation of aids to navigation and vessel traffic services world-wide.

RECALLING ALSO that Regulation 13 of Chapter V of the 1974 SOLAS Convention (as amended) requires:

1   Each Contracting Governments undertakes to provide, as it deems practical and necessary either individually or in co-operation with other Contracting Governments, such aids to navigation as the volume of traffic justifies and the degree of risk requires.

2   In order to obtain the greatest possible uniformity in aids to navigation, Contracting Governments undertake to take into account the international recommendations and guidelines [Reference is made by footnote to IALA] when establishing such aids.

NOTING that the responsibility of National Members for the safety of navigation and protection of the environment in waterways under their jurisdiction and that a number of National Members have requested guidance on means of assessing the risk of collisions and groundings, in order to address these issues;

NOTING ALSO that risk management studies have been carried out in various areas using different standards;

RECOGNISING that the safety and efficiency of vessel traffic and the protection of the environment would be improved if a risk management tool employing harmonised standards and criteria was used to assist National Members during the assessment of risks in waterways under their jurisdiction;

HAVING CONSIDERED the proposals by the Working Group on the development of a Generic Port and Waterway Risk Tool;

ADOPTS the IALA Risk Management Tool for Ports and Restricted Waterways as set out in the annexes to the present recommendation;

RECOMMENDS National Members to use the IALA Risk Management Tool for Ports and Restricted Waterways when assessing the risk of collisions and groundings in waterways under their jurisdiction, as part of their decision making process.

Table of Contents

4   THE NEED FOR TRAINING   22

Index of Figures

Annex 1 Policy and Principles

1   INTRODUCTION

The IALA Risk Management Tool comprises of two parts that are capable of:

- Assessing the risk in ports or restricted waterways, compared with the risk level considered by Authorities and stakeholders to be acceptable. The elements that can be taken into consideration include those relating to vessel conditions, traffic conditions, navigational conditions, waterway conditions, immediate consequences and subsequent consequences;

- Identifying appropriate risk control options to decrease the risk to the level considered to be acceptable. The risk control options available include improved co-ordination and planning; training; rules and procedures including enforcement; navigational, meteorological and hydrographical information; radio communications; active traffic management and waterway changes;

- Quantifying the effect on the risk level of an existing port or waterway that may result from a change or reduction of any of the risk control options in use.

The Risk Management Tool can also assist in assessing the risk level of existing ports and restricted waterways as well as determining the probable risk level of proposed new ports and waterways or if substantial changes to existing ports and waterways are being planned. The two parts, one of which conducts a Qualitative Risk Assessment and the other conducts a Quantitative Risk Assessment, can be used individually, sequentially or in parallel. A flow diagram of the procedure is given in Figure 1.

2   QUALITATIVE RISK ASSESSMENT

The Qualitative Risk Assessment tool has been developed by the US Coast Guard as the "Port and Waterway Safety Assessment tool" (PAWSA).

2.1   Overview

The PAWSA risk assessment process identifies major waterway safety hazards, estimates risk levels and consequences, evaluates potential mitigation measures, and sets the stage for implementation of selected measures to reduce risk.

PAWSA can provide an accurate risk assessment of an existing port or waterway in a short time frame and with limited expenditure. It is undertaken by carrying out a subjective assessment of the probability of risk in a waterway, based on the experience and expert opinion of stakeholders.

The assessment by this tool indicates whether the existing risk level in the waterway is:

- **Acceptable** and no further work is needed unless changes occur in important criteria, such as the traffic pattern or the types of ships using the waterway;

- **Not Acceptable** but the risk control options necessary to make the risk level of the waterway acceptable have been identified adequately;

- **Not Acceptable** and more detailed study is necessary to enable the risk control options that will make the risk level of the waterway acceptable to be identified adequately.

The PAWSA process has been completed in many ports/waterways in the US. The process has generally been well received by local maritime communities and resulted in some resounding successes. PAWSA is an effective process for evaluating risk and enabling local authorities and waterway communities to work toward long term solutions tailored to suit local circumstances. The aim of the process is to find solutions that are both cost effective and meet the needs of waterway users and stakeholders.

3   QUANTITATIVE RISK ASSESSMENT

The Quantitative Risk Assessment tool was originally developed by the Canadian Coast Guard in conjunction with the Danish Technical University and the Maritime Simulator Centre Warnemünde and is known as the "IALA Waterway Risk Assessment Programme" (IWRAP). This first software version of the tool provided somewhat pessimistic results, which lead to the development of a second generation of the software named IWRAP Mk II.

3.1   Overview

The IWRAP Mk II risk assessment process involves developing a model of the waterways to be analysed. The model describes the geometry of the relevant routes, the traffic volume and composition, as well as the bathymetry of the waterways in question. Once the model has been defined, IWRAP Mk II calculates the average annual number of collisions and groundings likely to occur. This calculation is based on the abovementioned model and a set of so-called Causation Factors which can be thought of as the probability that the vessel fails to make an evasive action in order to avoid the grounding or collision. IWRAP Mk II only addresses the *frequency* of collisions and groundings, it does not consider the consequences associated with these incidents. It is left to the Analyst and the authority performing the analysis to assess the possible consequences of the incidents, however, the output of IWRAP Mk II tool is well suited for such analysis to be performed subsequently once the calculation has been performed.

4   APPLICATIONS TO USE THE IALA RISK MANAGEMENT TOOL

Applications to use the IALA Risk Management Tool should be made by the Authority concerned to the IALA Secretariat. This will enable records to be maintained on the use of the Tool and, as the Tool is under constant review and upgrading, ensure that Registered Users are provided with the latest versions of both PAWSA and IWRAP as and when they are revised.

The application should indicate the waterway on which the risk assessment is to be done. On receipt of the application the IALA Secretariat will register the user and provide the latest version of both the PAWSA and IWRAP tools free of charge to the Authority.

The PAWSA CD contains all the information necessary to prepare and conduct a PAWSA risk assessment. However, if guidance is required the IALA Secretariat will arrange this in coordination with the United States Coast Guard.

Information on how to use the IWRAP tool is given through IALA IWRAP training seminars and on a dedicated IWRAP WIKI site on the internet (accessible through the IALA website). If further guidance or assistance is required the IALA Secretariat is able to arrange for experts to assist with conducting an IWRAP Risk Assessment.

Authorities are requested to provide copies of the results of risk assessments made by the IALA Risk Management Tool to the Secretariat.

Trigger event to start a Risk Assessment of the waterway. This could be, but is not limited to; accidents, technological change, proposed changes in traffic, or regular periodic inspection of the waterway.

People, Procedures, Policies, Practices

How Many, How Wide, How Long, How Deep, How do they navigate?

Qualitative PAWSA

Determine Type of Risk Assessment

Quantitative IWRAP

Yes

Did **Risk Assessment** indicate an acceptable level of risk?

Take no further action

Yes

Did **Risk Assessment** indicate an acceptable level of risk?

No

No

Are Risk Control Options identified adequately?

No

No

Yes

Implement Risk Control Options

Monitor Effectiveness of Risk Control Options *

* Monitoring the effectiveness of the risk control options should be an ongoing process that is revisited periodically. The monitoring should also indicate where to rejoin the process if unsatisfactory results are shown.

Figure 1   Risk Management Tool - Flow Diagram

Annex 2 – THE PAWSA TOOL

1   OBJECTIVE OF THE PAWSA RISK ASSESSMENT

The purpose of PAWSA is to provide Authorities and waterway communities with an effective tool to evaluate risk and work toward long term solutions tailored to local circumstances. The assessment should identify solutions that are cost effective and meet the needs of waterway users and stakeholders.

2   BACKGROUND

The PAWSA process grew out of the tremendous changes that took place during the 1990s in the United States Coast Guard (USCG) Vessel Traffic Service (VTS) Acquisition programme. As a result of this the USCG established the Ports and Waterways Safety System (PAWSS) to address waterway user needs and place a greater emphasis on partnerships with industry to reduce risk in the marine environment.

As part of PAWSS, the USCG immediately convened a national dialogue group (NDG) comprised of maritime and waterway community stakeholders to identify the needs of waterway users with respect to Vessel Traffic Management (VTM) and VTS systems.

From the NDG came the development of the PAWSA process, this opens a dialogue with waterway users and stakeholders to identify needed VTM improvements and to determine candidate VTS waterways. PAWSA provides a formal structure for identifying risk factors and evaluating potential mitigation measures through expert inputs. The process requires the participation of professional waterway users with local expertise in navigation, waterway conditions, and port safety. In addition, stakeholders are included in the process to ensure that important environmental, public safety, and economic consequences are given appropriate attention as risk interventions are selected.

3   PAWSA RISK ASSESSMENT METHODOLOGY OVERVIEW

3.1   General

The PAWSA risk assessment process is a disciplined approach to identify major waterway safety hazards, estimate risk levels, evaluate potential mitigation measures, and set the stage for implementation of selected measures to reduce risk. The process involves convening a select group of waterway users/stakeholders and conducting a two-day structured workshop to meet these objectives. An appropriate Authority is required to initiate and manage the workshop. However, the process must be a joint effort involving waterway users, stakeholders, and the agencies/entities responsible for implementing selected risk mitigation measures. The risk assessment process represents a significant part of joint public-private sector planning for mitigating risk in waterways.

The methodology uses a generic model of waterway risks. The only "safety" related issues that are deliberately excluded from the model are those that relate to port, facility, and vessel security. Those security-related issues are not covered during a PAWSA because the workshop is unclassified and usually open to the public whereas discussions of security issues may delve into sensitive topics that should be treated as classified information.

3.2   The Ports and Waterways Safety Assessment Workshop Guide

The Ports and Waterways Safety Assessment Workshop Guide (the PAWSA Workshop Guide) provides the guidance and procedures required for conducting a Ports and Waterways Safety Assessment. The PAWSA Workshop Guide is organized into seven sequential chapters that introduce the PAWSA process and then describe methodology, pre-workshop logistics requirements, participant selection, workshop preparation, session facilitation, and post-workshop reporting. Using this Guide as the primary reference, the appropriate Authority arranges for a meeting location and selects a group of waterway users and stakeholders from

the local community to participate in the workshop. During the workshop, participants discuss safety-related issues relating to the waterway and then provide numerical inputs to quantify those discussions.

3.3   Waterway Risk Model

Since risk is defined as the product of the probability of a casualty and its consequences, the Waterway Risk Model includes variables dealing with both the causes of waterway casualties and their effects. The six risk categories determined were:

1   **Vessel Conditions** – the quality of vessels and their crews that operate on a waterway.

2   **Traffic Conditions** – the number of vessels that use a waterway and their interactions.

3   **Navigational Conditions** – the environmental conditions that vessels must deal with in a waterway relating to wind, water movements (i.e., currents), and weather.

4   **Waterway Conditions** – the physical properties of the waterway that affect how easy it is to manoeuvre a vessel.

5   **Immediate Consequences** – the immediate impacts of a waterway casualty: people can be injured or killed, petroleum and hazardous materials can be spilled and require response resources, and the marine transportation system can be disrupted.

6   **Subsequent Consequences** – the subsequent effects of waterway casualties that are felt hours, days, months, and even years afterwards, such as shoreside facility shut-downs, loss of employment, destruction of fishing areas, decrease or extinction of species, degradation of subsistence living uses, and contamination of drinking or cooling water supplies.

The diagram below shows six risk categories and corresponding risk factors that are considered in the Model.

Waterway Risk Model					
Vessel Conditions	**Traffic Conditions**	**Navigational Conditions**	**Waterway Conditions**	**Immediate Consequences**	**Subsequent Consequences**
Deep Draft Vessel Quality	Volume of Commercial Traffic	Winds	Visibility Impediments	Personnel Injuries	Health and Safety
Shallow Draft Vessel Quality	Volume of Small Craft Traffic	Water Movement	Dimensions	Petroleum Discharge	Environmental
Commercial Fishing Vessel Quality	Traffic Mix	Visibility Restrictions	Bottom Type	Hazardous Material Release	Aquatic Resources
Small Craft Quality	Congestion	Obstructions	Configuration	Mobility	Economic

Figure 2   Waterway Risk Model Matrix

4   NUMERICAL METHODOLOGY

4.1   Theory

The theoretical concept underlying the PAWSA process is the proven Delphi method of converting the opinions of local subject matter experts into quantified results. This method is used so that the quantified results can be compared internally (i.e. the results for one risk factor can be compared to those for other risk factors and the results from one stage (e.g. Book 3) can be compared to the results from other stages (e.g., Book 4) during the workshop) and externally (i.e. the results from one waterway can be compared to the results from other waterways).

Proof that the PAWSA process produces valid results comes from the internal consistency checks that are built into the results spreadsheets within the Excel™ workbook (PAWSA software) used to capture and analyze the participants' quantified inputs. Those consistency checks have shown repeatedly that workshop participants develop strong consensus about the levels of risk in the waterway and the effectiveness of various risk mitigation strategies. This consensus emerges although the participants typically represent widely different interests within the overall maritime community and the 1 to 9 measurement scale used is correlated only loosely with qualitative descriptors for each value on that scale.

The rest of this paper describes the mathematics used to produce results from the quantitative assessments data (Books 1 – 5) the participants provide during a PAWSA workshop.

4.2   Book 1: Team Expertise

There is no expectation that every participant in a PAWSA workshop will be equally knowledgeable with respect to all 24 of the risk factors included in the Waterway Risk Model. Consequently, *Book 1: Team Expertise* is used to weigh the relative strengths of each team with respect to the six risk categories. After being presented with the concepts underlying the model, each participant team is asked to discuss (among themselves) how their background and experience aligns with the model. They then verbally present their conclusions to the larger group. These presentations give all teams a sense of where everyone thinks they are strong – or perhaps not so strong. After all teams have spoken, each team evaluates whether they think they are in the top, middle, or lower third of all teams present in knowledge about the six risk category areas. Throughout the workshop, these initial expertise evaluations are used to produce preliminary results for all other Books. Towards the end of the workshop, when each team has a much more in-depth feel for how all the teams compare to everyone else present, the team expertise evaluations are returned to each team for them to evaluate all of the other teams' level of expertise as well as to review and revise their own scores as necessary. The completed expertise evaluations are used to determine the final workshop results.

The teams, in doing the expertise evaluation, conceptually are dividing up six expertise pies (risk categories) into different sized slices, with the relative size of each slice from each pie equalling the expertise of each team relative to the other teams for that risk category. An example for the Navigational Conditions Risk Category:

    Team 1: Circles a 1 indicating they are in the Top 1/3 of all teams present;

    Team 2: Circles a 3 indicating they are in the Lower 1/3 of all teams present;

    Team 3: Circles a 1 indicating they, also, are in the Top 1/3 of all teams present.

These responses are entered into the data input cells in the *Bk 1 Input* spreadsheet in the Excel™ workbook. The spreadsheet then inverts those inputs, i.e., all inputs are subtracted from 4 so that a 1 becomes a 3 and a 3 becomes a 1. This is done so that the Top 1/3 teams get the biggest slice of the pie. Those inverted scores are added up (showing that, in our example, the total pie size = 3 + 1 + 3 = 7). Then each team's slice is computed by dividing their inverted score by the total pie size. For our example:

    Team 1: 3/7 = .429 (≈ 43% of the Navigational Conditions expertise pie);

    Team 2: 1/7 = .143 (≈ 14% of the Navigational Conditions expertise pie);

Team 3: 3/7 = .429 (≈ 43% of the Navigational Conditions expertise pie).

Obviously, and mathematically very important, adding all of the slices together equals 100% of each expertise pie.   These computations are done independently for each of the six risk categories (expertise pies). Each team's relative expertise in each category (size of their slice) is multiplied by their inputs for the four risk factors <u>in that category</u> during all of the other quantitative evaluations (*Books 2 – 5*). When this multiplication is done, the products that result are the weighted inputs for that team for that book. Because the sum of the expertise for each category equals 100%, the sum of the weighted inputs equals the risk level.

4.3   Book 2: Risk Factor Rating Scales

The concepts that define each of the 24 risk factors in the Waterway Risk Model have been described in qualitative terms, such that they range from a very benign, best case risk scenario to a highly dangerous, worst case risk scenario.   Two intermediate qualitative risk level descriptors describe risk somewhere between the best and worst cases, with the first intermediate descriptor less risky than the second intermediate descriptor.   Those qualitative descriptors have been refined over the course of many PAWSA workshops to remove ambiguities and use of multiple variables, both of which lead to poor consensus.

For uniformity, all risk assessment in the PAWSA workshop is done using a 1 to 9 point scale, where 1 represents the lowest risk and 9 represents the highest risk. The purpose of *Book 2: Risk Factor Rating Scales* is to establish the numerical relationships between the two intermediate qualitative risk descriptors and the best case and worst case end points. This is done with a pair-wise comparison technique, used to break up a complex problem (e.g. defining numerically how risk increases across a range of qualitative descriptions) into manageable component parts. Participant teams evaluate the increase in risk associated with moving from the lower risk descriptor in the left hand column of *Book 2* to the higher risk descriptor in the right hand column. Three pairs of comparisons are done for each risk factor. When the inputs from all participants for those three comparisons are aggregated, a risk rating curve results. The three comparisons for Wind Conditions are:

Strong winds occur **LESS** than twice a month **AND** well forecast	1 2 3 4 5 6 7 8 9	Strong winds occur **MORE** than twice a month **BUT** well forecast
Strong winds occur **MORE** than twice a month **BUT** well forecast	1 2 3 4 5 6 7 8 9	Strong winds occur **LESS** than twice a month **BUT** without warning
Strong winds occur **LESS** than twice a month **BUT** without warning	1 2 3 4 5 6 7 8 9	Strong winds occur **MORE** than twice a month **AND** without warning

Equally → Somewhat → Much More →Extremely
Risky   More Risky   Risky   More Risky

Figure 3   Wind Condition Comparisons

Continuing with the three team example from the previous section, hypothesize the following *Book 2* inputs for the Wind Conditions risk factor:

	Team 1	Team 2	Team 3
First Comparison	4	3	3
Second Comparison	7	5	6
Third Comparison	7	8	8

The inputs from each team for each risk factor in a particular risk category are multiplied by that team's expertise score for that risk category. For the example, that produces the following results:

	Team 1	Team 2	Team 3	Sum
First Comparison	4 x .43 = 1.72	3 x .14 = .42	3 x .43 = 1.29	3.43
Second Comparison	7 x .43 = 3.01	5 x .14 = .70	6 x .43 = 2.58	6.29
Third Comparison	7x .43 = 3.01	8 x .14 = 1.12	8 x .43 = 3.44	7.57
		Grand Total:		17.29

The first comparison is between the descriptor for the best case (which is called the "A" value) and the first intermediate descriptor (which is called the "B" value). The second comparison is between the "B" value and the second intermediate descriptor (which is called the "C" value). The third comparison is between the "C" value and the worst case descriptor (which is called the "D" value). The sums at the end of each row above show how much the risk increases going from the lower risk descriptor to the higher risk descriptor. Obviously the sum of those sums (17.29 in this example) represents the total increase in risk going from the best case to the worst case descriptors. On the 1 to 9 scale used throughout the rest of the PAWSA process (*Books 3*, *4*, and *5*), the best case is always assigned a risk level value of 1.0 and the worst case is always assigned a risk level value of 9.0. Note that the difference between those values is: $9 - 1 = 8$ points. From this information, it can be seen that the "B" risk level value equals the best case value (1.0) plus the sum of the first comparison products (3.43) divided by the total increase in risk going from the best to the worst case scenario (17.29) times the total distance along the 1 to 9 scale (8). Doing the math, the "B" value in this example equals:

$$B = 1.0 + (3.43 / 17.29 * 8) = 2.59$$

In like manner, the "C" value equals the "B" value plus the sum of the second comparison products (6.29) divided by 17.29 times 8, or:

$$C = 2.59 + (6.29 / 17.29 * 8) = 5.50$$

Finally, although it is already known that the worst case value always equals 9.0, it can be shown mathematically that that value equals the "C" value plus the sum of the third comparison products (7.57) divided by 17.29 times 8, or:

$$D = 5.50 + (7.57 / 17.29 * 8) = 9.0$$

Table 1   Typical results

A Value (Best Case Descriptor)	1.0
B Value (First Intermediate Descriptor)	2.5 to 3.0
C Value (Second Intermediate Descriptor)	5.0 to 6.0
D Value (Worst Case Descriptor)	9.0

To compare results from one workshop to another, all PAWSA workshops must use the same "aggregate" risk measuring scales. Those scales (one for each of the 24 risk factors in the Waterway Risk Model) are being developed through an iterative process wherein the *Book 2* results from each workshop are combined with the results from all previous workshops. This is done by simply averaging together the "B" values that were calculated during preceding workshops with the "B" values calculated for the current workshop. The same is done for the "C" values. This produces a four-point risk measuring curvilinear scale for each factor. The aggregate risk measuring curves thus defined are used as described in the next section.

4.4 Book 3: Baseline Risk Levels

To determine a risk level value for every factor in the Waterway Risk Model, *Book 3: Baseline Risk Levels* uses the same four qualitative descriptors for each risk factor as were used in *Book 2*. In theory those qualitative descriptors are written in absolute terms; that is, the risk level values that are produced by *Book 3* do not take into account any actions already implemented to reduce risk in the waterway. In practice, PAWSA participants sometimes have difficulty thinking in such absolute terms and the effects of existing mitigations tend to creep into the discussion and evaluation of this workshop stage.

Key to achieving strong consensus in the *Book 3* results is the discussion period that immediately precedes filling out this quantitative evaluation. During that discussion the various perspectives concerning each risk factor are voiced and, sometimes, debated. Often participants refer to read-ahead material provided for the workshop (or readily available to them via other means), especially for risk factors amenable to measurement and/or quantification (e.g., volume of traffic, wind conditions, cargo volumes). Once the discussions have run their course, participants simply check the box next to the qualitative descriptor for a particular risk factor that best matches conditions in the waterway being evaluated.

If a team checks the first box (describing the best case), then a 1 is entered into the *Bk 3 Input* spreadsheet, obviously corresponding to a value of 1.0 for that input. If a team checks the second box, then a 2 is entered into the spreadsheet and the computer algorithm assigns the "B" value from the aggregate risk measuring scale for that factor to that input. In like manner, a check in the third box is entered as a 3 and assigned the "C" value; a check in the fourth box (describing the worst case) is entered as a 4 and assigned a value of 9.0.

Building on the same three team Wind Conditions example from previous sections, hypothesize the following *Book 3* inputs:

	Team 1	Team 2	Team 3
Box Checked	Third	Second	Third
Spreadsheet Entry	3	2	3
Risk Value	C	B	C
Value Assigned	5.50	2.59	5.50

The inputs for each team for each factor are multiplied by their team expertise scores and then added together to produce the baseline risk value for that factor. Continuing our example:

	Team 1	Team 2	Team 3	Sum
Value Assigned	5.50	2.59	5.50	
Expertise Score	.43	.14	.43	
Product	2.36	.36	2.36	5.08

Thus, for the example, the baseline risk value for the Wind Conditions factor is 5.1. (Note: All results are displayed rounded to one decimal place because the qualitative descriptors that underlie these quantitative results are not precise enough for greater numerical precision.) The results from *Book 3* for each risk factor in the Waterway Risk Model become the baseline from

which the effectiveness of existing mitigation strategies are evaluated in *Book 4*. Those baseline numbers are marked on the *Book 4* assessment forms using a highlighter pen.

4.5   Book 4: Mitigation Effectiveness

Again, the key to good consistency in results from the *Book 4: Mitigation Effectiveness* stage is the discussion that immediately precedes filling out the quantitative evaluations. Those discussions focus on three issues: (1) the specifics of what has been done to reduce the risk associated with a particular factor; (2) the effectiveness of those mitigation actions; and (3) whether existing mitigations are well balanced with the baseline risk value.

Once the discussions are complete, the participants do two things: (1) circle a number on the 1 to 9 scale that shows the effectiveness of existing mitigations in reducing risk below the absolute levels determined via *Book 3* and (2) circle Yes (or No) depending on whether they think existing mitigations adequately balance the risks for each factor (or not).

The vast majority of the time, participants will circle a number on the 1 to 9 scale to the left of (smaller than) the highlighter mark denoting the *Book 3* result. However, if they conclude that actions taken previously are having no effect on reducing the baseline risk, they will circle the *Book 3* result mark. Though unusual, participants might state (and then evaluate) that existing mitigations actually increase the risk for some factor(s). For example, while discussing the Dimensions risk factor, participants cite as an existing risk mitigation strategy that leading lights have been established to help waterway users keep from running aground in a narrow channel, but state that the leading lights are out of alignment with the channel, thereby increasing the risk of groundings. They then could evaluate the effect of that mitigation by circling a higher number (i.e., to the right) of the *Book 3* result mark.

The numbers that are circled by the participants are entered exactly as indicated into the *Bk 4 Scores* spreadsheet with two exceptions: (1) if the participants circle the space between two whole numbers, the entry is invalid and the team is required to reassess providing a whole number entry; and (2) if the participants circle the *Book 3* result mark, a lower case "e" is entered and the computer algorithms convert that entry into the *Book 3* results value.

As with *Books 2* and *3*, the *Book 4* numerical entries are multiplied by the *Book 1* expertise scores and then those products are added together to produce the present risk level, which takes into account the effectiveness of existing mitigations.

Continuing the example from previous sections:

	Team 1	Team 2	Team 3	Sum
Number Circled	3	Highlighter mark	4	
Spreadsheet Entry	3	e	4	
Value Assigned	3	5.08	4	
Expertise Score	.43	.14	.43	
Product	1.29	.71	1.72	3.72

Rounding this result to one decimal place, it can be seen that the effectiveness of existing mitigations in reducing Wind Conditions risk is judged to be: 5.1 – 3.7 = 1.4 points.

As the final step in *Book 4*, participants make a subjective evaluation, based on the preceding discussions, as to whether they think risks are adequately balanced with existing mitigations for each factor. They do this by circling Yes (they are balanced) or No (they are not balanced) on the line in *Book 4* for each factor. Those Yes / No answers are coded into the *Bk 4 Y-N* spreadsheet as lower case "y" or "n". If two thirds or more of the participant team expertise indicates Yes, then that risk factor is dropped from further discussion / evaluation in *Book 5: Additional Mitigations*. This condition is denoted by a green *Balanced* on the *Book 4* results display spreadsheet (*Bk 4 Disp*). If two thirds or more of the participant team expertise

indicates No, then that risk factor should definitely be discussed / evaluated in *Book 5*. That condition is denoted by a red *NO* on the *Book 4* results display. If there is less than two thirds consensus about the efficacy of existing mitigations then a yellow *Maybe* is displayed. Those "Maybe" risk factors also should be discussed / evaluated in *Book 5*. Finally, if the present risk level is evaluated as being HIGHER than the risk level from *Book 3* or, when appropriate, is higher than the risk level determined during a previous PAWSA held for the same waterway, then a red *RISING* is shown on the *Book 4* results display.

4.6   Book 5: Additional Mitigations

In the final quantitative evaluation stage of the PAWSA process, discussion is focused on those risk factors where the present risk level is not *Balanced*. For each risk factor displaying a *NO*, *RISING,* or *Maybe* flag, the *Book 4* results are marked using a highlighter on blank copies of the *Book 5: Additional Mitigations* evaluation forms. This serves as a starting point for evaluating the possible effectiveness of new mitigation strategies. For each risk factor so marked, the workshop participants are asked to offer ideas about what should be done to reduce the present risk level. Again, the quality of the discussion directly affects consistency of results obtained.

Analysis of risk mitigation ideas offered to date showed that those ideas usually fall into nine major implementation categories. Those categories are:

- Co-ordination / Planning;
- Voluntary Training;
- Rules & Procedures;
- Enforcement;
- Navigation / Hydrologic Information;
- Radio Communications;
- Active Traffic Management;
- Waterway Changes;
- Other Actions.

Those categories are fully described on a handout given to participants and also are defined on the first page of *Book 5*.

After the participants have presented / discussed their risk mitigation ideas, they are asked to write short phrases (3 to 5 words each) describing the ideas they think have merit. Those short phrases are written on the lines next to the categories into which the ideas best fit. For example, if the risk factor being discussed is Wind Conditions and the idea being considered is "Install wind sensor at Long Point", then the participants would write those words on the line next to the Nav / Hydro Info intervention category under that risk factor. After recording an idea, the participants indicate what risk level would result from implementing that idea. This is done by circling a number to the left of (lower than) the *Book 4* risk level mark on the 1 to 9 scale next to the implementation category where the idea was written. As in *Book 4*, only whole numbers are used; therefore, if the participants circle the space between two whole numbers, the entry is invalid and the team is required to reassess providing a whole number entry. The closer that circle is to 1, the more effective the participant team feels the idea to be. Those evaluations are again multiplied by the team's expertise scores and then those products are added together to get the possible risk level resulting from implementing the ideas written down for a particular category.

Again using the Wind Conditions example:

	Team 1	Team 2	Team 3	Sum
Number Circled	2	3	2	
Spreadsheet Entry	2	3	2	
Expertise Score	.43	.14	.43	

Product	.86	.42	.86	2.14

The algorithms for the *Book 5* display spreadsheet (*Bk 5 Disp*) determine which implementation category most teams have chosen and then how much risk improvement would result from the ideas written down for that category. Those *Book 5* display algorithms also determine which implementation category was judged to be most effective (i.e., had the biggest delta between the *Book 5* and *Book 4* results). A yellow *Caution* flag is displayed if the most chosen implementation category is NOT the same as the most effective category AND either fewer than 50% of the teams chose the most chosen category OR more than 50% of the teams chose the most effective category. The presence of the yellow *Caution* flag for any risk factor indicates the possibility that there is more than one "best" mitigation measure that potentially will achieve further risk reduction for that factor.

4.7 Workshop Outputs

Workshop outputs should include electronic and paper copies of a participant contact list, workshop critique comments, and the *PAWSA Workshop Report*. The *PAWSA Workshop Report* should include the quantitative results from *Books 1 – 5*, discussion comments made during the workshop, and an in-depth analysis providing specific recommendations as to the mitigation strategies that should be implemented and the organizations that should take the lead in implementing them.

Annex 3 – THE IWRAP TOOL

1   OBJECTIVE OF THE IWRAP TOOL

The purpose of the IALA Waterway Risk Assessment Program (IWRAP Mk II) is to provide Authorities with a standardised quantitative method to evaluate the probability of collisions and groundings in a given waterway. IWRAP Mk II allows different scenarios to be developed, so that changes in traffic volume or composition, changes in route geometry, changes in the mix of Aids to Navigation or the introduction of other mitigating options, may be evaluated in terms of changes in the average annual number (probability) of collisions and groundings.

2   BACKGROUND

IWRAP has evolved from a probabilistic methodology for estimating the probabilities of groundings and collisions, developed at the Technical University of Denmark, inspired by the work of Fujii and MacDuff in the 1970´s and the "Minimum Safe Design" (MSD) tool originally developed in Canada and used by the Canadian Coast Guard.

When the first version of IWRAP was initially tested, the results obtained seemed credible and in accordance with the accident statistics in the considered area and experts were satisfied with the results. However, at a later stage, when the tool was applied to other areas it yielded an unrealistic high number of collisions and groundings. In 2007 the IALA Risk Management Steering Group decided to initiate the development of a second generation of IWRAP. Thanks to the dedicated efforts of a team of IALA members, research institutes and universities, lead by the Danish Maritime Safety Administration (DAMSA), a new tool, named IWRAP Mk II, was developed from scratch and validated. The first training seminar dedicated to IWRAP Mk II was held in Kuala Lumpur, Malaysia in April 2009 using the Malacca Strait as a test case for training purposes.

IWRAP Mk II is a purely probabilistic tool, i.e. the MSD channel design criteria's implemented in the first version of IWRAP are not included in IWRAP Mk II.

3   IWRAP MK II RISK ASSESSMENT METHODOLOGY OVERVIEW

IWRAP Mk II is implemented as a MS-Windows ™ based application that forms the framework for the process of defining a model of the waterway being analysed. The IWRAP Mk II Risk Assessment process involves the following steps:

- Defining Bathymetry, Routes, Waypoints and Legs;
- Entering Traffic Volume Distributions on each Leg;
- Defining Traffic Lateral Distribution;
- Grounding due to Drifting;
- Defining other traffic in the area;
- Selection Causation Probability Factors;
- Result calculation and assessment.

Usually the Analyst would just assess the results in terms of annual number of collisions and groundings, by setting up a baseline waterway scenario and comparing other scenarios to the baseline. If a cost benefit analysis of different mitigating options is required, the Analyst would use the output of IWRAP Mk II to further assess the consequences of the resulting collisions and groundings.

3.1 Defining Bathymetry, Routes, Waypoints and Legs

The first step of developing an IWRAP Mk II waterway model is to obtain as much information as possible on the geometry of the waterway, its bathymetry and its route layout. The bathymetry information can be obtained from Nautical Charts while information about the routes can best be obtained from AIS data, statistically processed to generate a so-called Density Plot. If such a plot is not available, route layout information may be obtained from other sources.
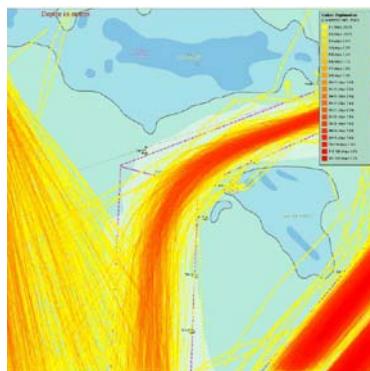
Figure 4   Waterway Density Diagram derived from AIS data (not the same waterway as in figure 5)
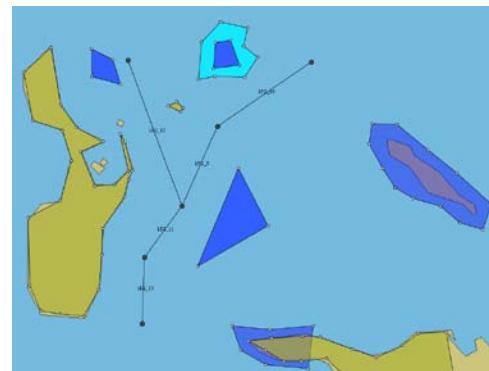
Figure 5   IWRAP Waterway model derived from AIS data and a Nautical Chart

This information is entered into the IWRAP Mk II programme using its Geographic Model Editor, resulting in a model similar to the one in the figure above.

3.2 Entering Traffic Volume Distributions on each Leg

Once the route layout has been defined, the Analyst needs to enter information about the traffic volume and the traffic composition in each direction on each route leg, using the Traffic Editor.
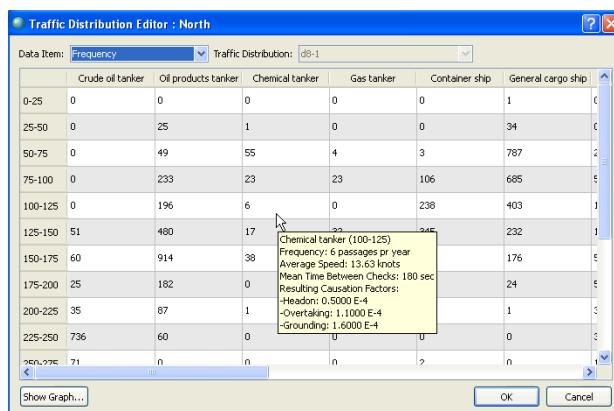
Figure 6   Traffic Volume Editor used for entering information about vessel traffic volume and composition.

IWRAP Mk II uses 14 different types of vessel categories each of which is divided into a number of length categories. The information about the number of vessels in each category can be obtained from AIS data.

3.3 Defining Traffic Lateral Distribution

Having defined the bathymetry, the route layout, waypoints and route legs as well as the volume and composition/types of the vessels on each leg, the Analyst needs to define how the vessels are distributed laterally on each leg in each direction. This is done using the IWRAP Mk II leg editor.
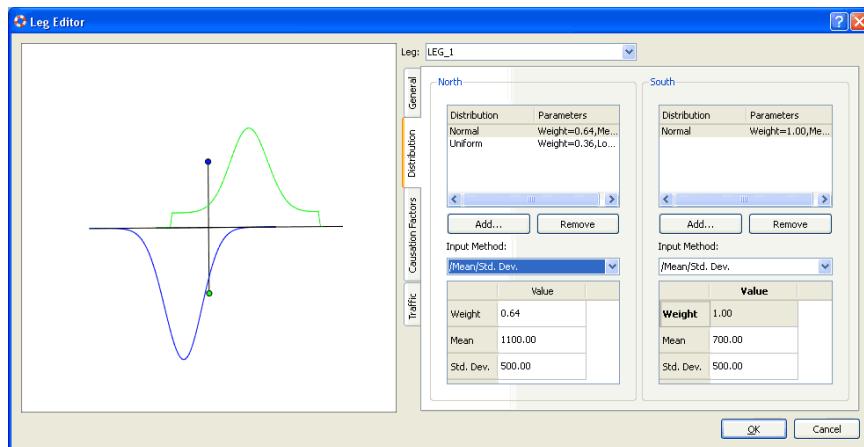
Figure 7   Route Leg editor used for entering information about lateral distribution of vessels on a route leg.

Information about the lateral distribution of vessels can be obtained from AIS data. This is done by defining a passage line perpendicular to the route leg and counting all vessels crossing the passage line while noting their lateral position on the passage line. The resulting lateral distribution can then be entered manually into IWRAP Mk II using one or more of the predefined standard distributions supported by IWRAP Mk II.

3.4   Grounding due to Drifting

IWRAP Mk II is capable of modelling ships that run aground while drifting due to a power outage / blackout. The Blackout Frequency can be defined and the time taken to recover from the blackout (Repair Time) can be expressed in probabilistic terms (Figure 8). Also the probability of drifting direction can be defined (Figure 9).
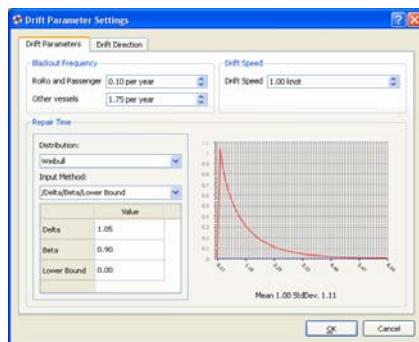

Figure 8   Blackout frequency and the time it takes to recover from a blackout can be defined.
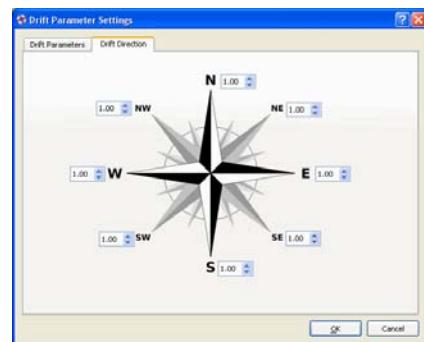
Figure 9   The probability of drifting in a given direction during a blackout can be defined.

3.5   Defining other traffic in the area

Most of the information about traffic volume and composition entered into IWRAP Mk II is usually obtained from AIS data. However there may be a number of non AIS vessels such as fishing vessels and leisure boats in the area of interest. There is a certain probability of collision with such objects. This can be modelled with IWRAP Mk II by assuming a certain density of fishing vessels and leisure boats per unit area per year.
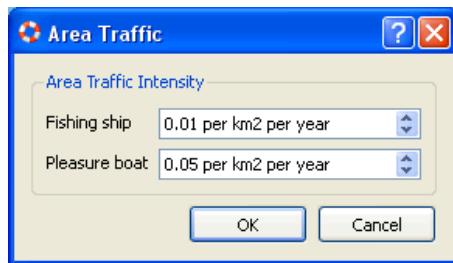
Figure 10   Density of non-AIS vessels in a given area can be specified

This model is rather crude since it assumes a uniform density of such objects across the whole geographic region being modelled. However it gives some idea of the risk of colliding with such objects.

3.6   Selecting Causation Probability Factors

A very important part of every IWRAP Mk II model, are the so-called Causation Factors used within the model. The Causation Factors can be thought of as the probability that the vessel fails to make an evasive action in order to avoid the grounding or collision.

A number of default factors have been selected as the IALA default Causation Factors:

Condition	Causation Factor
Head on collisions	$0.5 \cdot 10^{-4}$
Overtaking collisions	$1.1 \cdot 10^{-4}$
Crossing collisions	$1.3 \cdot 10^{-4}$
Collisions in a bend situation	$1.3 \cdot 10^{-4}$
Collisions in a merging situation	$1.3 \cdot 10^{-4}$
Grounding – forgot to turn	$1.6 \cdot 10^{-4}$

These factors have been carefully selected on the basis of a careful literature study and are believed to be suitable as default factors and applicable in most parts of the world.

However the IWRAP Mk II allows the Analyst to modify these factors should that be desirable. If the default IALA Causation Factors are modified in a waterway model, the Analyst should state this fact in his/her report.

3.7 Result calculation and assessment

Once the waterway model has been defined IWRAP Mk II can calculate the resulting annual average collisions and groundings. The results can be displayed in tabular form or graphically using colour coding as shown in the figures below:
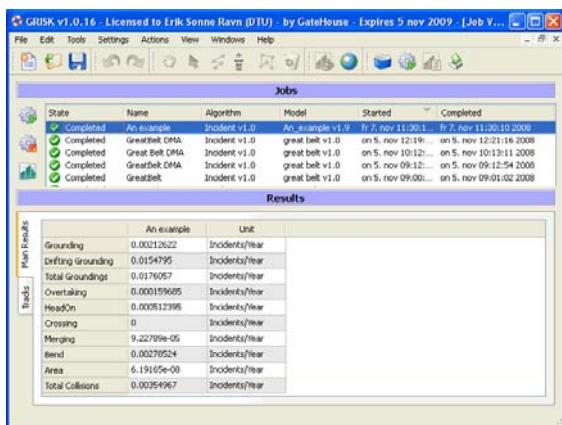

Figure 11   Tabular result view

Figure 12   Geographical result view using Colour Coding

From the tabular result display (Figure 9) the Analyst is able to assess what types of collisions and groundings are most likely to occur. From the geographical result display (Figure 10), the Analyst is able to assess where the collisions and groundings are most likely to occur.

Once a baseline result has been calculated, the Analyst can adjust the waterway model to account for any desired changes within the waterway. Several scenarios can then be compared in order to perform sensitivity analysis and evaluate different risk mitigating options.

IWRAP Mk II only addresses the *frequency* of collisions and groundings it does not consider the consequences associated with these incidents. It is left to the Analyst and the Authority performing the analysis to assess the possible consequences of the incidents, however, the output of IWRAP Mk II tool is well suited for such analysis to be performed subsequently.

4   THE NEED FOR TRAINING

It should be noted that IWRAP II is an advanced, very flexible calculator useful for creating models of waterways and to analyze the level of risk expressed as incident rates in these waterways. The quality of the analysis is entirely in the hands of the Analyst, who must make a number of choices, such as selecting the route layout, estimate traffic density and distribution and select causation factors. Therefore it is essential that the Analysts using IWRAP Mk II are properly trained and fully capable of understanding the implications of their choices.