Level of Sustainable Activity: Moving Visitor Simulation from Description to Management for an Urban Waterway in Australia

Robert M. Itami
GeoDimensions Pty Ltd
16 Tullyvallin Crescent
Sorrento, Victoria
Australia 3943
Bob.Itami@geodimensions.com.au

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Abstract
Visitor pattern of use simulations are an effective tool for describing and human movement in a variety of environments (Cole, 2005). Visitor simulations studies use paradigms such as discrete-event simulation, cellular automata and multi-agent simulation. However, regardless of the methodology used, the outputs are always the same – a quantitative description of movement patterns. Whereas the quantitative analysis of visitor flows is fundamental to a better understanding of the complex interactions of human use with the environment, the impacts on the quality of experience and behaviour can only be discovered through social science methods that elicit responses from users about their expectations, attitudes, preferences and behavioural responses to visitor densities, queuing times, flow rates, and the capacity of facilities. This chapter presents a decision-making framework called “Level of Sustainable Activity” (LSA) that links the outputs of agent based river traffic simulations to social and environmental performance objectives. The method is adapted from the US Federal Highway Administrations “Level of Service” for traffic capacity. However the LSA framework links user estimates of traffic density to quality of service objects and a risk management framework to identify social and environmental risk factors. The results of the method are then used to interpret simulations of existing and projected use for making management decisions.

Introduction:
Visitor pattern of use simulations are an effective tool for describing and quantifying the distribution, density, speed, and flow patterns of human movement in a variety of environments from wilderness back-country settings to highly urbanised high use settings (Cole, 2005). The technical development of special purpose simulators for recreation environments continues using simulation paradigms including discrete-event simulation, cellular automata and multi-agent simulation. However, regardless of the methodology used to simulate visitor pattern of use, the outputs are always the same – a quantitative description of movement patterns. Whereas the quantitative analysis of visitor flows is fundamental to a better understanding of the complex interactions of human use, the
impacts of these patterns on the quality of experience and behavior can only be discovered through social science methods that elicit responses from users about their expectations, experiences, attitudes, preferences and behavioral responses to visitor densities, queuing times, flow rates, the distribution of destinations, and the capacity of facilities. Only by linking the social and environmental implications to the flow patterns generated by human pattern of use simulations can we begin to manage the quality of experience for visitors.

This issue is at the heart of a complex management problem in Melbourne, Victoria Australia. The Melbourne Waterways Committee commissioned a study in 2005-2006 to determine the traffic capacity of the Maribyrnong and Yarra Rivers (see figure 1) to develop a traffic management plan on the basis of the current level of river traffic and the projected traffic for the next 5 and 10 year periods. The urgency for this study is prompted by existing conflicts between commercial passenger ferries and rowing and canoeing, and the increasing commercial and recreational traffic in the shipping zone. On top of this is the Melbourne Docklands development, which will create marinas for 700 to 1000 new private and public berths in the heart of the study area (see figure 1).

Earlier consultancies had established projected growth rates for commercial and recreational traffic, however a defensible method for determining river capacity for the various forms of traffic had not been determined. The underlying assumption had been that some single metric like “maximum number of vessels per hectare” could be established to determine the overall capacity of the river system. This definition, however does not recognize the very different physical operating characteristics of a rowing skull compared to a passenger ferry, or the quality of experience required for passive recreation versus competitive training. It is clear a robust defensible way of defining river capacity that takes into account river characteristics, competing users, vessel types, and physical infrastructure had to be developed.

Study Method

The Yarra and Maribyrnong Rivers and Port Phillip Bay in Victoria, Australia are complex environments. Located in an urban environment, their physical characteristics are diverse. Large shipping docks, commercial tourist berths, boat launching ramps and active recreation clubs support a diverse range of river traffic from cargo ships to commercial tourist operators, private motorized craft and rowers. These users share use of a restricted area of water and naturally have their own, sometimes-divergent views about how they and others they share the river with should be managed.

River traffic management must:

- Balance the competing demand of a diverse set of different types of users
- Maintain and enhance the significant commercial values of the water in terms of the operation of the Port of Melbourne and commercial tourist operators who operate throughout the study area
- Consider the safety and quality of experience of the many recreational users of the rivers and bay.
• Consult and incorporate the views of the many organizations involved in managing traffic on the two rivers and bays.

A multi-faceted approach is required to meet these requirements. Figure 2 below describes the approach taken in the Two Rivers Traffic Management Plan.

Insert Figure 2

The Two Rivers Traffic Management Plan consists of four main components:

1. **Inventory**
   A detailed inventory of the physical characteristics of the waterways. Geographic data and locations of all major facilities was recorded and mapped in Geographic Information System (GIS). The inventory included a reconnaissance level assessment of erosion risk of river banks.

2. **Management and User Group Interviews**
   Various management organisations and User groups were interviewed in detail to obtain their views on river traffic management and the issues important to them. Feedback from interviews was used in the following ways:
   a. To define key traffic issues relating to quality of service, safety, and environmental impacts, conflicts between user groups and current traffic management issues.
   b. As an input to the simulation scenarios in the form of estimates of future traffic volumes and new future facilities;
   c. As an input to the simulation scenarios in the form of alternative management actions to be tested.

3. **Level of Sustainable Activity Workshop and Interviews**
   The Level of Sustainable Activity (LSA) component uses the statistics and information collected in the inventory component to formulate a series of densities for motorized and non-motorized river traffic for each river management zone. Five LSA levels designated with the letters A to E define the relationships between traffic density and quality of service. LSA A is the lowest density and the highest quality of service and LSA E is the highest density and the lowest quality of service.

   Insert Table 1

4. **LSA focus group workshops** then collected the preferences and views of the main user groups of the waterways about existing and future traffic levels and river facilities. The LSA workshops asked river users to rate existing peak and maximum tolerable traffic levels on the water. The LSA component results were used to
   a. Define existing LSA levels for each River Management Zone at peak periods of use
   b. Define maximum LSA levels while still maintaining safe navigation and quality of service objectives
   c. Define impacts and risks to quality of experience, safety, environment
e. Suggest means of mitigating or managing these impacts and risks.

5. Simulation
The fourth component of the Two Rivers Traffic Management Plan involved building a series of simulations of existing and forecast future traffic levels. The outputs of the simulations gave a spatial view of the changes in traffic densities and volumes from 2005 to 2010 and 2015. The Level of Sustainable Activity results were a crucial input to evaluating the simulations. Two alternative management options of river closures and speed limit changes were tested in the simulation process. The simulation was built using a special purpose recreation behavior simulator RBSim (Itami et al., 2004).

This chapter will focus on the Level of Sustainable Activity framework as applied to the analysis of river traffic management using the results of a single river management zone (Marina Transit Zone) as an example.

Level of Sustainable Activity for River Traffic
The Level of Sustainable Activity (LSA) concept is a generalization of the Level of Service concept developed by the Transportation Research Board (2000). River capacity is different for each user group and varies in relation to river geometry, vessel characteristics, the provision of facilities, and the interaction with other users. River traffic management must therefore be based on a comprehensive framework that integrates all the relevant factors in a format that is easy for users and decision makers to understand and that can be adapted to a wide range of environments and travel modes.

LSA can be thought of as a scale of end-user experience. Each river zone has a range of service levels defined for each vessel type ranging from very low levels of use, with minimal environmental and social impacts to high-density use with high levels of user interaction, higher levels of potential environmental and social impacts, and more intensive facility and management requirements.

The LSA concept integrates:

- Physical characteristics of the river, including navigable depth, width, and bank erosion potential. This information was available by taking measurements from aerial photographs, bathometric surveys of river depth and from on-site survey of bank conditions for each river management zone.
- Physical characteristics of different vessel types, their stopping distance and safe passing distance and speed (described in more detail below)
- Defining traffic densities for each LSA (A through E) for motorized and non-motorized vessels
- User preferences for levels of use for specific activities in specific river zones.
- User attitudes toward competing traffic Safety, Environmental and Social risk factors relating to increasing use densities.
- Suggestions from users on management options for dealing with the above risks.

1.1 Characterizing River Management Zones
Insert Figure 3
The LSA framework requires that the environment that is under evaluation is homogenous in terms of physical configuration, mix of users and facilities. Previous studies of the 2 Rivers study area had formulated a sensible classification of the rivers and bay into 7 river management zones. These zones were homogenous for the characteristic required for the LSA framework. However, the Port Zone and the Bay Zones were not included in the LSA study due to lack of time and resources and the predominance of large commercial shipping in these zones. Each river zone is characterized according to total area in hectares, length and the average width of the navigable area. This information is measured from aerial photography and bathometric surveys. These dimensions are then used to calculate traffic densities at different use levels. In addition existing facilities relating to river use were inventoried for each River Zone.

An important factor in the environmental impact of the river is the bank erosion caused by wash from boats. The risk of erosion is related to bank conditions and the type and speed of vessels. Based on existing information on bank protection, evidence of bank slippage and expert opinion, the banks are rated on a relative scale from low to high for erosion risk. The risk factor is then compared to different levels of use by vessel type to determine the erosion hazard and mitigation options. Erosion risk is a highly complex and technical issue that varies significantly in the study area. Therefore, a qualified fluvial geomorphologist made an expert assessment of erosion risk.

1.2 Physical Characteristics of Vessels

Characteristics of the vessels shown in were collected from operators, manufacturer’s specifications and from expert feedback. These vessels were then grouped into two major subgroups to simplify the presentation of traffic to users. The two groups are:

- Motorized Vessels
- Non-Motorized vessels (rowing shells and canoes)

Commercial Shipping and Passenger Cruise ships were not included in the LSA since their movements are strictly regulated and they always have right of way because of their size, weight, limited maneuverability and the danger they pose for other vessels. Table 2 shows vessels included in the Motorized and Non-Motorized Vessel classes.

1.3 Establishing LSA Levels

In order to establish the traffic density at each of 5 LSA levels (A through E). The following factors have to be considered:

1. The type of vessel including its length, width (including oars for rowing), power and speed (translated into safe stopping distance with reverse thrust for powered boats)

2. The navigable width of the river

3. Navigation rules, in particular, staying to the right of on-coming traffic.

Insert Table 2
Operating characteristics of vessels is affected by speed, length, width, waterline depth and power. These factors affect the ability of the operator to avoid collisions with other vessels. In the LSA framework a set of equations were used to calculate stopping distance with reverse thrust (see Figure 4). These equations were run on a range of vessels with different weights, at the range of speeds allowed in each river zone. These calculations provide a safe distance in front of the vessel that allows the vessel to avoid collisions with stationery craft in the path of the boat traveling at a given speed.

The problem is complex because of the highly variable operating characteristics of the different vessels, however the problem, in the case of the 2 Rivers study could be simplified because the speed limit in each of the river zones studied was set at 5 knots/hour (9.26 km/hr). Speeds were determined by taking the minimum of the speed limit for the river as compared to the maximum speed of the vessel. A second simplification was to average the stopping distances of different vessels within the motorized and non-motorized vessel classes to create “typical” stopping distances for the evaluation.

A computer program was written to generate random patterns of boats separately for motorized traffic and rowing and paddling. The program incorporates the physics equations with spacing rules and navigation rules. The program works by randomly selecting locations and sizes for each vessel, if the new location meets the rules for navigation, safe operating envelope and spacing rules for horizontal and longitudinal proximities to other boats and the riverbank, then the boat is allocated to that position. If any of the rules fail, then the program generates another random location and tests for the same rules again. As the river segment fills up the rules are systematically relaxed until it is no longer possible to allocate any more boats to the river segment at this point the river is “jammed” and the program stops.

Random allocation produces similar densities at the lower levels for both motorized and non-motorized vessels. As densities increase however differences in stopping distances cause greater differences in the density levels of the two classes of vessels as shown in Table 3. Note that LSA levels A through C increase at a geometric rate (1, 2 and 4 vessels per hectare). LSA level D category however between Rowers/Canoeists and Motorized vessels. As Level D represents the “safe operating envelope” for a hypothetical “average” vessel in this zone the difference is attributed to differences in size, weight, speed and power. LSA level E represents the river zone with maximum number of vessels with all constraints relaxed. Level E therefore represents a crowded traffic level where vessels would need to slow down to navigate safely with operators having to be constantly vigilant to avoid collision with other vessels.

1.4 Focus groups to determine LSA level preferences

The preferences of different river users are key component of the management of river traffic and the definition of river capacity. Each river user-type (rowers, commercial tour operators, water taxis, and ships) has different requirements in terms of safety, ability to
perform their intended activity, and level of satisfaction based on the mix and density of vessels sharing the river zone. In the LSA framework two situations were addressed:

- Activity within a single user group (e.g. Rowers in relationship to rowers or commercial vessels in relationship to other commercial vessels) and
- Level Sustainable Activity between different users (e.g. rows in relationship to commercial vessels).

For each of these categories there is also difference in expectations during busy times of the day and season and during off-periods. A reliable way of making these judgments was needed.

First, users were divided into focus groups with no more than 12 participants in each focus group. The main categorizations were:

- Large Commercial Operators
- Small Commercial Operators
- Rowers and Paddlers

The large and small commercial operators were asked to evaluate LSA levels in three river zones they typically use:

- Marina Transit Zone
- Commercial Zone
- Active Recreation Zone

Rowers were similarly asked to evaluate LSA levels only in the river zone they used, there for the rowers were divided into three groups:

- Maribyrnong Rowers (Maribyrnong Zone)
- Rowing Clubs downstream of Herring Island (Active Recreation Zone)
- Rowing Clubs Upstream of Herring Island (Passive Recreation Zone)

The reason for separating out users in this fashion was to avoid conflict during workshops (it was known from previous questionnaires that there was considerable animosity between commercial operators and rowers), to ensure users were concentrating on their quality of service issues and when there was disagreement on LSA evaluations, consensus could be achieved through discussion between peers in a congenial environment. Government officials were excluded from observing or participating in the focus group meetings.

In order to elicit responses from the focus groups on LSA levels, plan view representations of each of the 5 LSA levels generated by the computer program described earlier, were overlaid on aerial photos to provide users with an accurately scaled image of each LSA level for motorized and non-motorized vessels. Examples of the LSA levels for the Marina Transit Zone are shown in
The users were then asked to identify the peak period of use by season, day of week and hours in the day. Once the peak use period(s) was defined, the users were then asked to identify LSA levels for the following conditions:

- Current LSA during peak periods for OTHER users during YOUR peak period
- Maximum tolerable LSA during YOUR peak period
- Maximum tolerable LSA for OTHER users during YOUR peak period

The users were allowed to discuss differences in their evaluations and then through group discussion came up with a consensus for each of the 3 evaluations. This process defines the current peak period densities, the maximum LSA that users are willing to accept for their own group and for competing users.

After the above LSA levels were determined the focus groups were asked to identify risks to safety, quality of experience, and impacts on environment as traffic increased or exceeded the maximum tolerable LSA level. This discussion was then followed by discussion of options for resolving or mitigating these risks.

**Results and Discussion – Commercial Zone**

The LSA framework proved to itself for defining river capacity from a user’s perspective as well as stimulating focussed discussion on the implications and responses to increasing traffic as traffic volumes exceed accepted levels of traffic. To demonstrate the findings from the LSA framework described above, the results from the Commercial Zone will be discussed. The Commercial Zone has a mix of recreational and Commercial traffic with many conflicts between the two user groups, it therefore is a good test of the LSA framework, to identify the issues, river capacity and user responses to increasing levels of use over time.

Figure. 6 shows the upstream half of the Commercial Zone, this area is a major hub for river tourist activity with commercial ferries, tour boats and restaurant boats originating in this zone. In addition, rowers from the adjacent Active Recreation Zone share the zone especially near Princes Bridge where rowers make a U-turn to return upstream on training runs. Elite rows also traverse through this zone enroute to the Marina transit zone downstream where there are long straight stretches of river favoured for race training by this group.

The Commercial Tourist Zone hosts a high level of traffic volumes mostly due to the high intensity tourist-oriented business along the south bank of the Yarra River and the high levels of pedestrian traffic generated by the zone’s proximity to Melbourne’s CBD. Many commercial passenger services originate or terminate in this zone. The zone also acts as a transit corridor for rowers and motorized recreation boats. Rowers in the Active Recreation Zone also turn downstream of Princes Bridge near the Southgate commercial berths causing conflict during the busy tourist season. Bank erosion is low risk in this zone because the banks are fully lined with concrete or stonewalls.
The Commercial Tourist Zone is currently used predominately by commercial passenger services. With many visitor attractions including Southgate, Melbourne Aquarium, Crown Casino, the Melbourne Exhibition Centre and Polly Woodside, this zone currently has a high level of pedestrian use and provides a strong market for commercial operations. The zone has heavy traffic not only because of the demand, but also because the zone is relatively small. Even if current traffic levels are within acceptable levels for users, the restricted navigable area means that there is little excess capacity.

Insert Table 4
Insert Figure 5
Insert Figure 6

1.5 Commercial Tourist Zone Level of Sustainable Activity Results

Table 4 shows the physical characteristics of the commercial zone along with the major tourist destinations accessible from the Yarra River.
Figure 7 through Figure 11 shows LSA levels A through E for motorized traffic in the Commercial Zone. A similar set of exhibits were generated showing the five rowing LSA classes. These were used in the LSA focus groups for Commercial Operators and for Rowers.

Insert Figure 7
Figures 8, 9, 10, 11

Table 5 shows the results of the LSA focus group with commercial operators. It shows this group has low tolerance for mixed traffic with rowers and that the zone is nearing maximum capacity.

Insert Table 5

Commercial operators also noted problems with poor night lighting at Spencer Street Bridge and on river bends. Also of concern was the training for new vessel captains. With the complexities of tidal effects, night conditions, river flows, flooding and competing river traffic it can take a year to "learn the ropes".

Conflicts with other river users include “unpredictable behavior” and speeding by motorized recreation vessels, unexpected turning by rowers, “verbal abuse” by rowers and coaches and rowing instructors often being unaware of safety issues with mixed traffic. However commercial operators generally agreed that all users have legitimate use of the river.

**Commercial Tourist Zone Simulation Results**

Table 6 shows total hourly traffic for the peak use day simulated for 2005, 2010 and 2015 within the Commercial Tourist Zone. Traffic volumes more than double between 2005 and 2010 and then level off approaching 2015 as marina capacities are reached. Densities of vessels increase rapidly in this zone because of its small area (16.27 Hectares). By 2010 densities typically reach LSA Level B at 11am and by 2015 LSA Level C is reached. In reality peak LSA levels are likely to be higher than those shown by the simulations. Areas with commercial berths and many bridges would be likely to be associated with localized traffic congestion making the LSA levels higher.

Insert Table 6

Figure 12 shows the pattern of use by travel mode. The early morning traffic is primarily elite rowers passing through the area to train between Charles Grimes Bridge and Bolte Bridge. Later in the morning the dominant traffic becomes commercial passenger and motorized recreation vessels. Commercial traffic declines sharply in the mid-afternoon, increases in the after-work hours and gradually declines into the evening.

Insert Figures 12 & 13

Figure 13 shows that by 2010 motorized recreational traffic is the dominant use in the Commercial Tourist Zone due to the large number of Docklands berths now available. Increased motorized traffic in 2010 will impact upon rowing.

Insert Figure 14
Figure 14 shows the 2015 traffic pattern of use that was established in 2010 continuing. Again morning rowing extends later into the morning and motorized recreation and commercial passenger services show steady increases in volume.

**Commercial Tourist Zone Traffic Management Issues**

Motorized recreation is the biggest challenge for traffic management in the Commercial Tourist Zone. The high variability in the skills and experience of recreational boaters, the narrowness of the channel, and the complex movement patterns of commercial passenger vessels transiting to and from berths increase the risk of near misses and collisions. Commercial operators in this zone reported that there would be a lowering in quality of service for passengers in the form of delays and waiting times and higher stress on captains of vessels due to the often-unpredictable behavior of recreational boaters if current peak period LSA levels are exceeded.

Options for management include improving user education, compliance with navigation and speed rules, or limiting motorized recreation traffic by restricting access during peak hours of commercial use. Other mechanisms include instituting a “no overtaking” rule in this zone. This would have the affect of generating single file traffic, minimising the number of manoeuvres that would generate cross traffic and near misses.

Given that the current peak periods exceed the LSA, river traffic in this zone needs to be monitored carefully over the next few years including regular consultation with key user groups. The monitoring is to be targeted at identifying key high risk behaviors. In consultation with the commercial operators and other peak user groups develop vessel operating and zoning rules to reduce the likelihood and consequences of an incident occurring.

**Comments on LSA Focus Groups**

Since the methods used in this study are novel, it is worth making comments on the effectiveness of using user focus groups for evaluating LSA levels for river traffic. The major points are listed below:

- LSA framework is easy for users to relate to.
- Plan view-images of LSA levels overlaid on aerial photos is an effective method for eliciting responses from river users.
- User’s were able to make quick, spontaneous judgments of peak period LSA levels and were able to come to consensus quickly after brief discussion.
- Users were similarly able to make judgments of LSA levels for other users
- Users were able to make judgments relating to maximum tolerable LSA levels for their own use and the use levels for other users.
- Discussion of LSA levels generated discussions relating to safety, quality of service and the nature of conflicts between different users. This information when linked to the LSA levels helps define the rationale for defining river capacity level for each group and between groups. This information is supported by information from face to face interviews.
The LSA framework is a valid method of determining River Traffic Capacity from a user’s perspective.

**User based LSA ratings compared to simulated LSA**

Another aspect of the river management study methodology is the duo use of user-based LSA evaluations and computer simulated river traffic densities to inform management decisions. Ideally there should be good coincidence between these two evaluations, however there are differences, which are discussed here.

Generally there is good coincidence between user evaluations of river traffic densities at the lowest end of the scale (LSA A 0-1 boats per hectare), however as densities increase the user estimates of density are generally lower than the simulated densities. This discrepancy can be caused by the following factors:

- Simulated traffic volumes are under-estimated
- User estimates of traffic volumes are over-estimated
- User estimates are based on key locations and times within the zone when traffic is especially dense.

In reality the discrepancy is most likely due to a combination of the above factors. The simulation estimates of density are based on 4 sample counts per hour. These counts are then averaged and divided into the hectares for the river zone. This means traffic is averaged over time and space. The implications of this is that if the heaviest traffic occurs, say early in the hour, then this peak density is averaged with the remaining three counts for the hour which would lower the hourly density for the zone. Also if use is concentrated in a specific location in the zone, say at commercial berths or at boathouse launch sites, the high densities at these locations are averaged across the entire zone.

When users were asked to evaluate LSA levels they were instructed to give ratings during their “peak period of use”. This would naturally prompt them to imagine the “worse case scenario” or the busiest times. For rowers on the Yarra in the Active Recreation Zone, for instance this would be during the early morning training periods when school rowers and elite rowers are all launching at the same time. For commercial operators in the Commercial zone, this would likely be at commercial berths. This would mean that users over estimated average densities for the zone.

The exact reasons for the discrepancy would have to be determined through follow up observations during busy periods. However the above explanation is probably close to the mark. The issue is what impact this discrepancy has on traffic management decisions. First it should be noted that the user LSA evaluations are seen as relative to the current situation. In other words, they are making judgments about traffic densities relative to the quality of service they desire. In this context the user LSA ratings can be used as a benchmark against current conditions. The likely impact of increases in traffic on users can then be estimated based on their assessment of current LSA levels and peak periods and the maximum tolerable LSA for the river zone. The simulation results may then be interpreted against these relative evaluations. The issues raised by users relating to boating safety and impacts on quality of service still provide valuable guidance to
management decision-making, even if the exact evaluations of traffic density are in-
accurate.

Conclusions

The LSA framework has proven to be a robust way of obtaining user-based definitions of river capacity, quality of service and the consequences of increasing traffic. The quantitative definition of LSA developed for river traffic was useful in interpreting the results of river traffic simulation. The use of focus groups to illicit current and maximum acceptable LSA levels for mixed traffic was efficient, easy to employ and stimulated positive and constructive feedback on the current conditions, desired conditions and the consequences of exceeding desired LSA levels.

The LSA framework will be developed further in other environmental contexts and other recreational settings and should be applicable across a broad range situations where there are competing demands for limited environmental resources.

Further research needs to be done to get better coincidence between LSA levels identified in workshops and traffic densities generated in simulations. However the flexibility of the framework for handling mixed and competing uses in a wide range of environments supports its further refinement and development.

Acknowledgements

I would like to thank Parks Victoria and especially David Ritman and Paul Dartnell who provided intelligent guidance and feedback throughout the project. Lindsay Smith and Glen MacLaren with Ennoscapes and Environmental Systems Solutions respectively for their assistance in data collection, analysis and visualization for the project. Colin Arrowsmith, Department of GeoSciences at Royal Melbourne Institute of Technology for data collection and analysis of river traffic monitoring data, Simon McGuiness of RM Consulting Group who acted as facilitator at the LSA focus group meetings.

Literature Cited


Figure 1: The “2 Rivers” study area – Looking south, downstream to Yarra River to the left, Victoria Harbour and the Docklands development center right, and Bolte Bridge and the Port of Melbourne in the background flowing into Port Philip Bay on the horizon.
Figure 2 Overview of the Two Rivers Management Plan Methodology
Table 1: This table shows the relationship between Level of Sustainable Activity, Traffic Density and Quality of Service. As traffic densities increase, Quality of Service decreases.

<table>
<thead>
<tr>
<th>Level of Sustainable Activity</th>
<th>Traffic Density</th>
<th>Quality of Service</th>
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<tbody>
<tr>
<td>A</td>
<td>Low Density</td>
<td>Highest</td>
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<td>B</td>
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<td>C</td>
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<td>D</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>E</td>
<td>High Density</td>
<td>Lowest</td>
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Figure 3: The “2 Rivers” study area – Port Phillip Bay to the south and the 7 river management zones.
Figure 4: A safe operating envelope was calculated based upon the stopping distance of the vessel under maximum reverse thrust.

Table 2: Vessel classes in the Level of Sustainable Activity Study

<table>
<thead>
<tr>
<th>Motorized Vessels</th>
<th>Non-Motorized Vessels</th>
<th>Commercial Shipping (not include in the LSA evaluations)</th>
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<td>• Rowing shells</td>
<td>• Bulk Carriers</td>
</tr>
<tr>
<td>• Cruising / Function Boats</td>
<td>• Canoes</td>
<td>• Container ships</td>
</tr>
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<td>• Water Taxis</td>
<td>• Sail boats</td>
<td>• Passenger Cruise ships</td>
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<tr>
<td>• BBQ Boats</td>
<td></td>
<td>• Tug boats and Pilot boats</td>
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<tr>
<td>• Small powered speed boats</td>
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<tr>
<td>• Large cruising motor boats</td>
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<td></td>
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<tr>
<td>• Victorian Water Police</td>
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<th>Quality of Service</th>
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<td>5,000 m²</td>
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Table 2: Vessel classes in the Level of Sustainable Activity Study
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<tr>
<td>E</td>
<td>625 m²</td>
<td>16</td>
<td>714 m²</td>
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Table 3: Level of Sustainable Activity vessel density definitions for Rowers/Canoeists and Motorized vessels. LSA level A is the lowest density and the highest quality of service. LSA level E is the highest density and lowest quality of service. This table allows the manager or analyst to link outputs from the river traffic simulation to quality of experience or river users.

Figure 5 Location map for Commercial Tourist Zone, Melbourne CBD directly north.
Figure. 6: Upstream section of the Commercial Zone looking upstream on Yarra River. Princes Bridge near the top of the photo marks the boundary with the Active Recreation Zone. Southbank development to the right and Flinders Rail Station to the left and Sandridge rail bridge at the bottom of the photo. This area is a popular tourist zone with many restaurants and sidewalk cafes as well as close proximity to downtown Melbourne, the arts district and major sporting facilities.
<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
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<tbody>
<tr>
<td>Typical River Width in Zone</td>
<td>75-100 m</td>
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<tr>
<td>Zone Length</td>
<td>1.9 km</td>
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<tr>
<td>Area of Navigable Water</td>
<td>16 ha</td>
</tr>
<tr>
<td>Bank Erosion Risk Rating</td>
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<tr>
<td><strong>Major Features / Destinations</strong></td>
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</tr>
<tr>
<td>South Wharf Function Centre</td>
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</tr>
<tr>
<td>Polly Woodside / Melbourne Maritime Museum</td>
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</tr>
<tr>
<td>Melbourne Convention Centre</td>
<td></td>
</tr>
<tr>
<td>Melbourne Exhibition Centre</td>
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</tr>
<tr>
<td>Crown Casino and Entertainment Complex</td>
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<tr>
<td>Melbourne Aquarium</td>
<td></td>
</tr>
<tr>
<td>Southgate and Commercial Tourist Berths</td>
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<tr>
<td>Flinders Street Station</td>
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</tr>
<tr>
<td>Flinders Walk Landing</td>
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<tr>
<td>Banana Alley Wharf</td>
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<tr>
<td>Enterprise Wharves</td>
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<tr>
<td>Princes Bridge</td>
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Table 4 Commercial Zone Characteristics
Figure 7 Level A Level of Sustainable Activity Motorized Boats Commercial Zone
Flinders Station rail yard to top of picture, Southbank at the bottom, Princes Bridge to the right and Queens bridge on the left (Sandridge Bridge is not shown in this image).

Figure 8 Level B Level of Sustainable Activity Motorized Boats Commercial Zone
<table>
<thead>
<tr>
<th>Vessel Type</th>
<th>Current LSA at peak periods</th>
<th>Maximum tolerable LSA</th>
<th>Management Implications</th>
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<tr>
<td>Commercial</td>
<td>C+</td>
<td>C-D</td>
<td>Near Capacity</td>
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<tr>
<td>Rowers</td>
<td>A+</td>
<td>A+</td>
<td>Low tolerance to rowers</td>
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**Table 5 Results of LSA focus group evaluations by Commercial Operators**

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**Table 6: Hourly traffic volumes and densities for the Commercial Tourist Zone with projections for 2010 and 2015. Densities are vessels per hectare.**
Figure 12 2005 hourly traffic for Commercial Tourist Zone by Travel Mode

Figure 13 2010 hourly traffic for Commercial Tourist Zone by Travel Mode
Figure 14 2015 hourly traffic for Commercial Tourist Zone by Travel Mode