Modern Marina Layout & Design

Certain characteristics of recreational boats — mainly beam and draft — heavily influence slip layout and basin dredging depth criteria in marina design.

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The perception exists that new recreational boats are enclosing more volume in a given length, with greater beams, higher superstructures and more draft. Is this situation really occurring, or are marina operators simply putting the largest boats possible into marina slips?

Figures 1 and 2 illustrate how a marina operator, tempted by higher revenue, can squeeze oversize boats into slips designed for smaller vessels. These overlength boats extend far beyond the slip fingers, restricting the fairway width for other boats. The boat shown in Figure 2 does not have sufficient slip width clearance, and fenders barely fit between the finger docks and hull. Note that there are exhaust appendages near the waterline on either side of the hull, increasing the beam of this vessel. It is not surprising that the skipper of this boat had to wedge the boat into the slip bow first.

Despite the evidence of some slip overloading, a comparison of boat dimensions from the past few decades does indicate a trend toward increasing beam and draft for powerboats and sailboats.

With boat beam and draft increasing, do existing marina design guidelines need revising? To check existing guidelines and to extract additional marina design information, two databases were recently compiled for recreational powerboats and sailboats of lengths likely to be found in a marina. Data on the critical dimensions and other key features of many different recreational powerboat and sailboat designs were compiled from magazine advertisements, boat brochures and sales listings both in this country and overseas. These characteristic boat dimensions, and their relationship to dock layout, are illustrated in Figures 3 and 4. Boat or slip length is given as L; slip width (clear width) is given as W.

The powerboat database consists of 1,500 different designs of boats from 6.1 m (20 ft) to 65 m (213 ft) in length. Such features as overall length, beam, draft, displacement, standard fuel type and capacity were recorded, if available.

A similar sailboat database was compiled from 1,100 designs of boats from 2.4 m (8 ft) to 48.5 m (159 ft) in length. Sailboat information included overall length, waterline length, beam, minimum and maximum drafts (with available keel options), and fuel capacity.

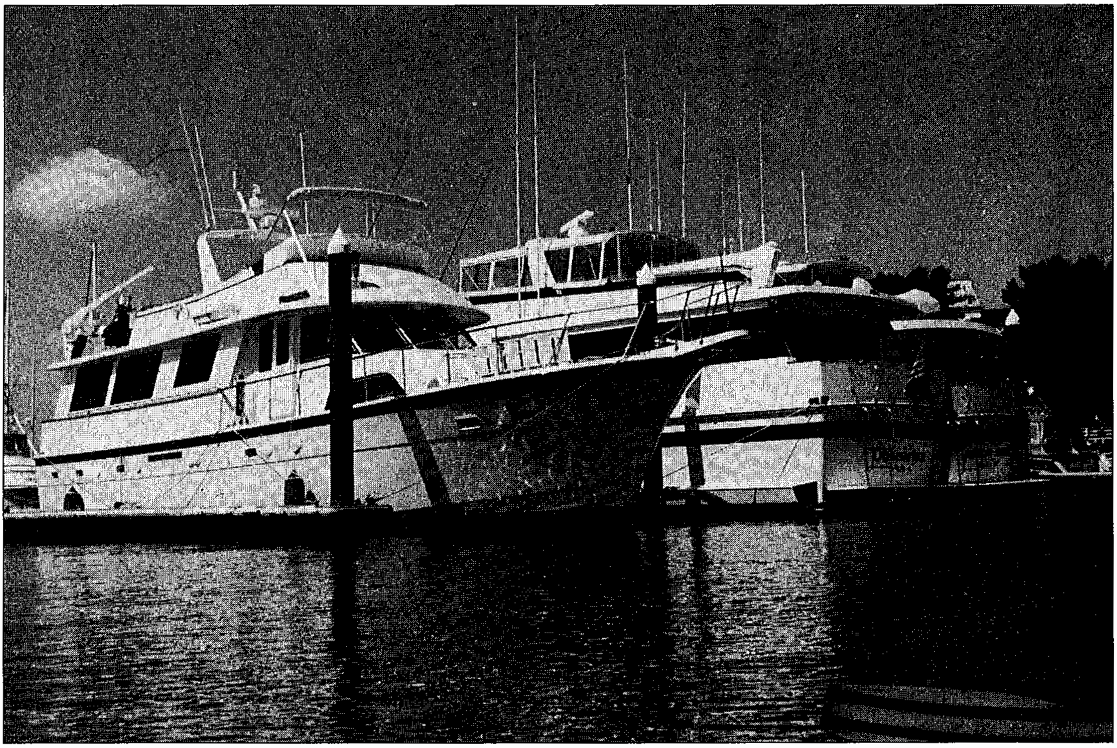

FIGURE 1. Overlength boats.

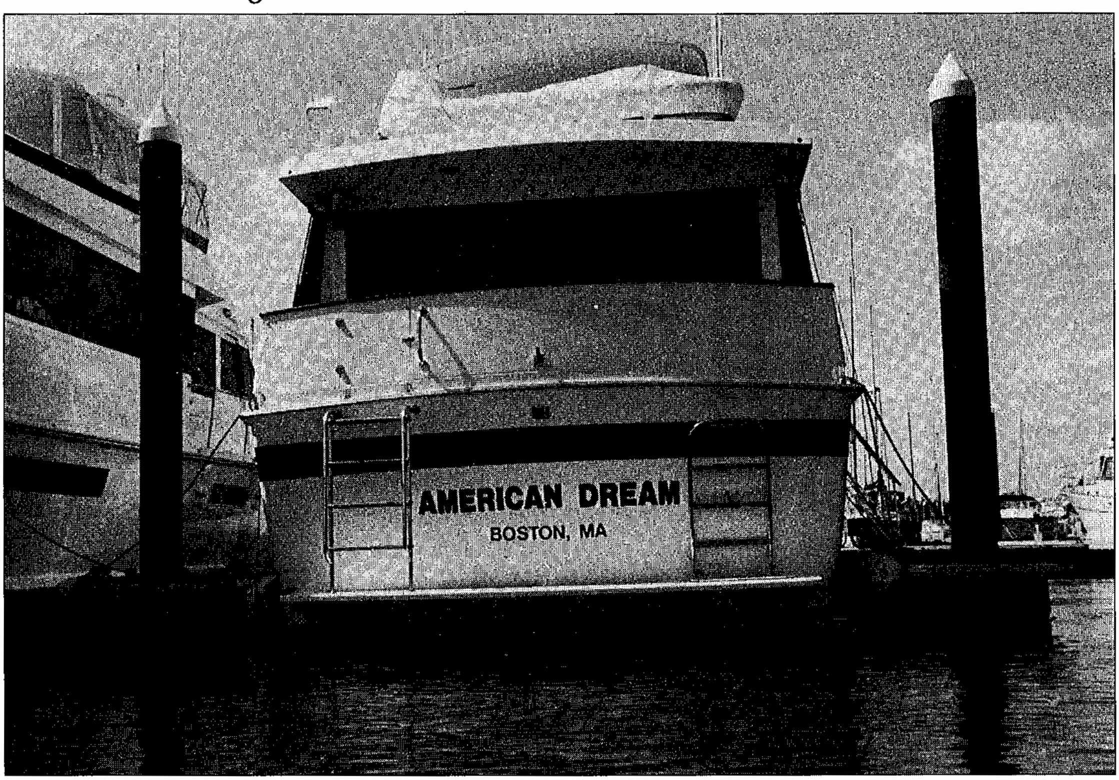

FIGURE 2. Overwidth boat.

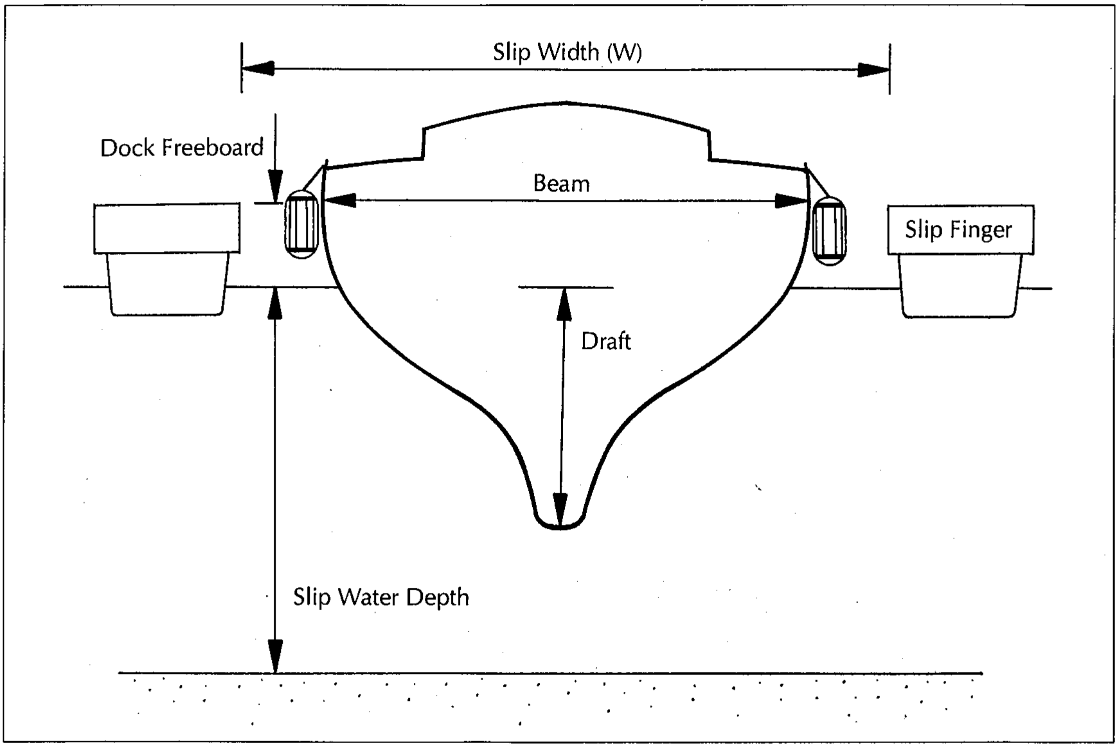

FIGURE 3. Boat and slip characteristics.

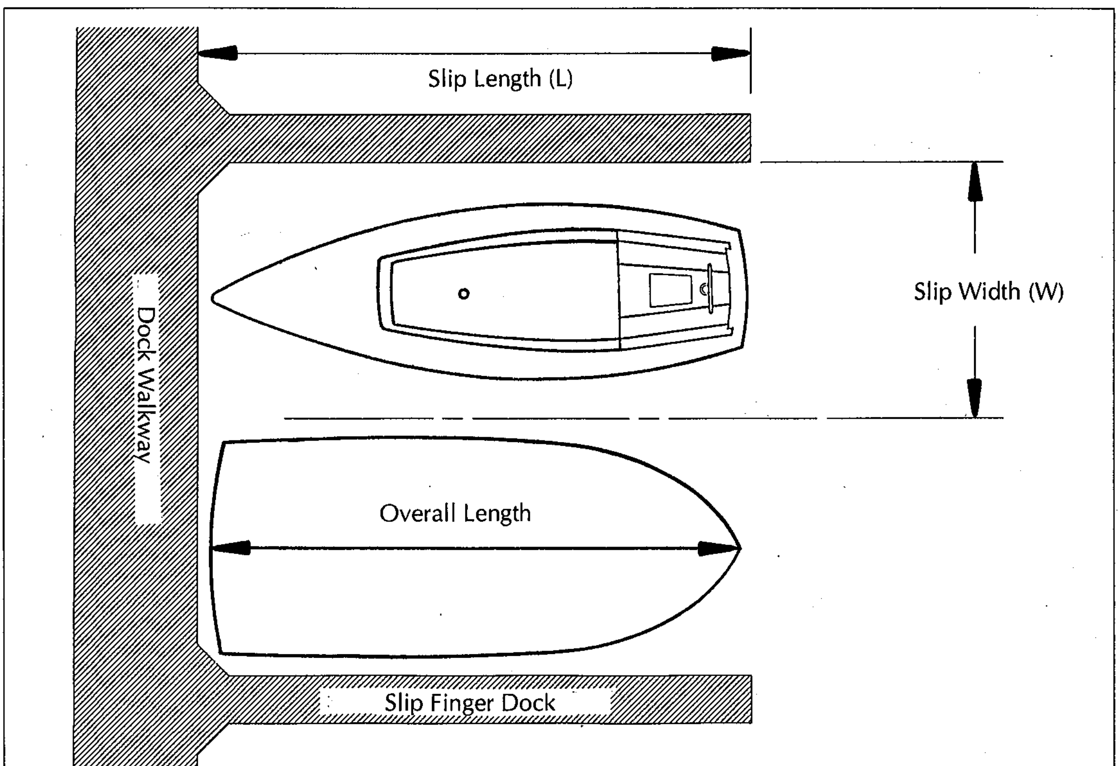

FIGURE 4. Typical double slip plan.

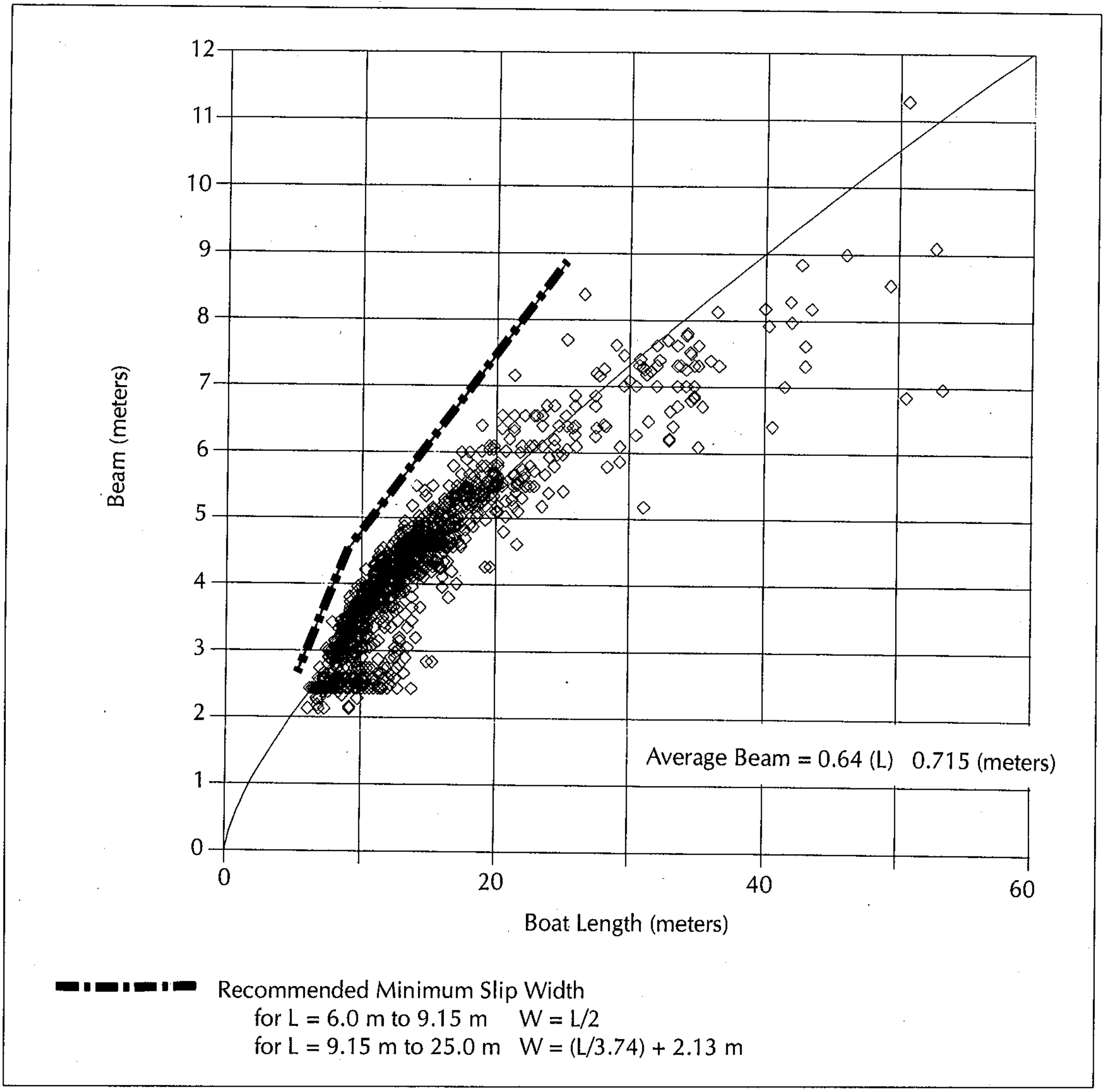

FIGURE 5. A plot of powerboat beam against overall boat length.

Unusual boats or boat types specific to localized areas, such as houseboats, multihull sailboats and commercial fishing boats, were not included in the databases. These boat types do not usually comprise a significant population in most coastal marinas and, if necessary, slips can be specifically designed for these types of vessels.

These two databases formed the basis for developing new marina layout and design recommendations. Potential applications for these recommendations include the setting of marina slip widths, dry stack and dry storage layout, basin dredging depths, berthing energy evaluation, boat lift selection and determination of pavement loading. A comparison of these recommendations with a number of guidelines published over the last two decades served as a means of further refining the recommendations.[1-5]

Beam

Perhaps the most important marina layout parameter is slip width. This parameter sets the number of slips that can fit into a given area, the cost per slip ratio and the marina operational performance for the next few decades.

The database beam information was plotted

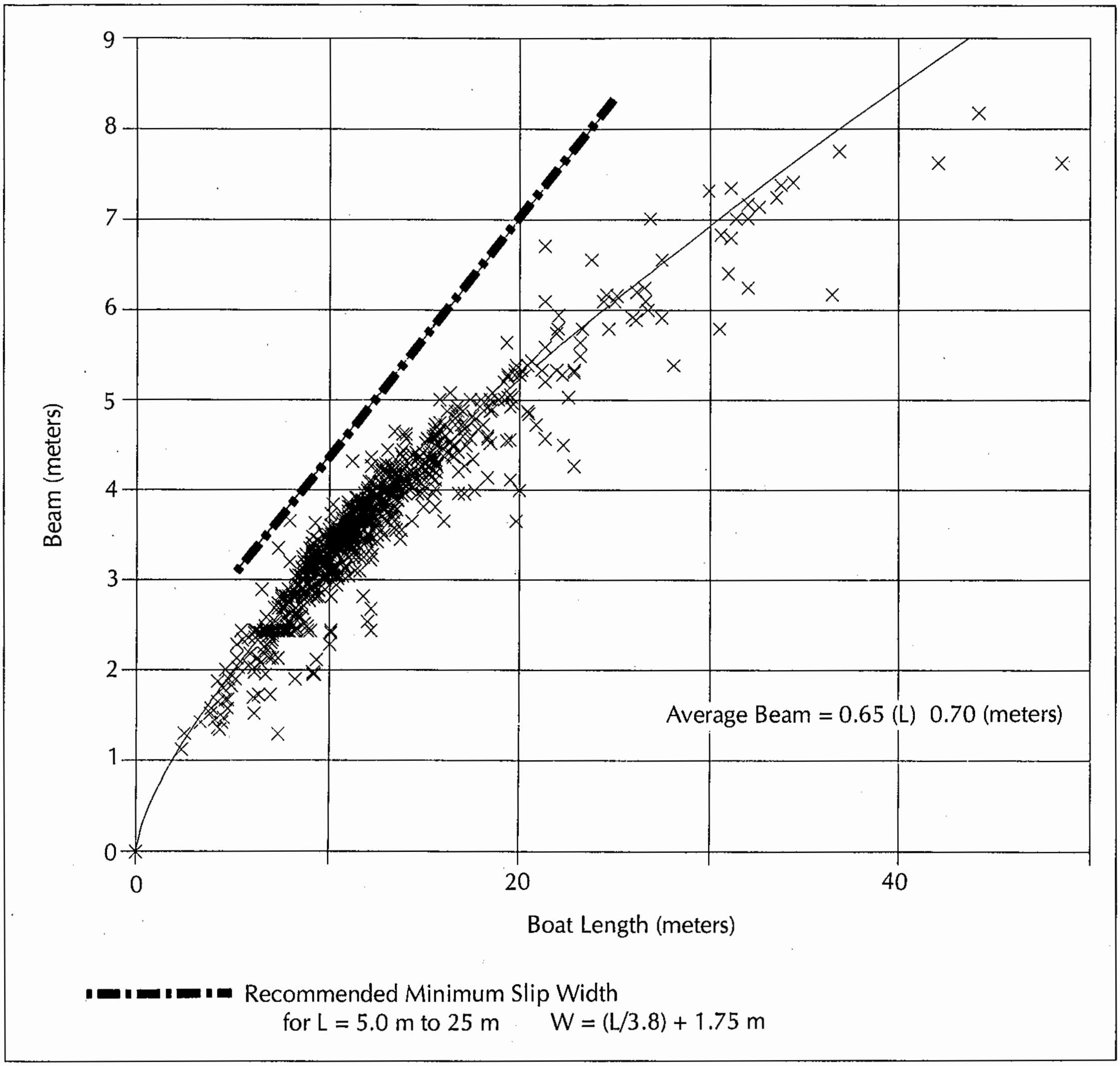

FIGURE 6. A plot of sailboat beam against overall boat length.

against overall length for powerboats and sailboats to form new design recommendations (see Figures 5 and 6). If this relationship was between beam and waterline length, data scatter induced by differing styles of bows, sterns, bow pulpits and swim platforms would be reduced. However, overall boat length was chosen for this application, since it more closely represents slip length.

Best-fit curves were applied to these data to represent the typical powerboat or sailboat likely to be found in a marina slip. The mathematical formula of power equations were selected because they meet the lower boundary condition of zero beam at zero boat length. A comparison of the plotted data indicates that powerboats generally have a wider beam than sailboats, but this beam difference is typically half a meter or less.

To turn these boat beam data into useful marina design tools, lines have been fit to the data to represent the recommended minimum clear slip width required to safely berth a given size boat at a floating dock. These recommended slip width lines have not been extended to boats longer than 25 m (82 ft). The beam dimensions of these large boats become quite varied and they are often berthed at the tee ends of docks, not in slips.

How do these updated slip widths compare

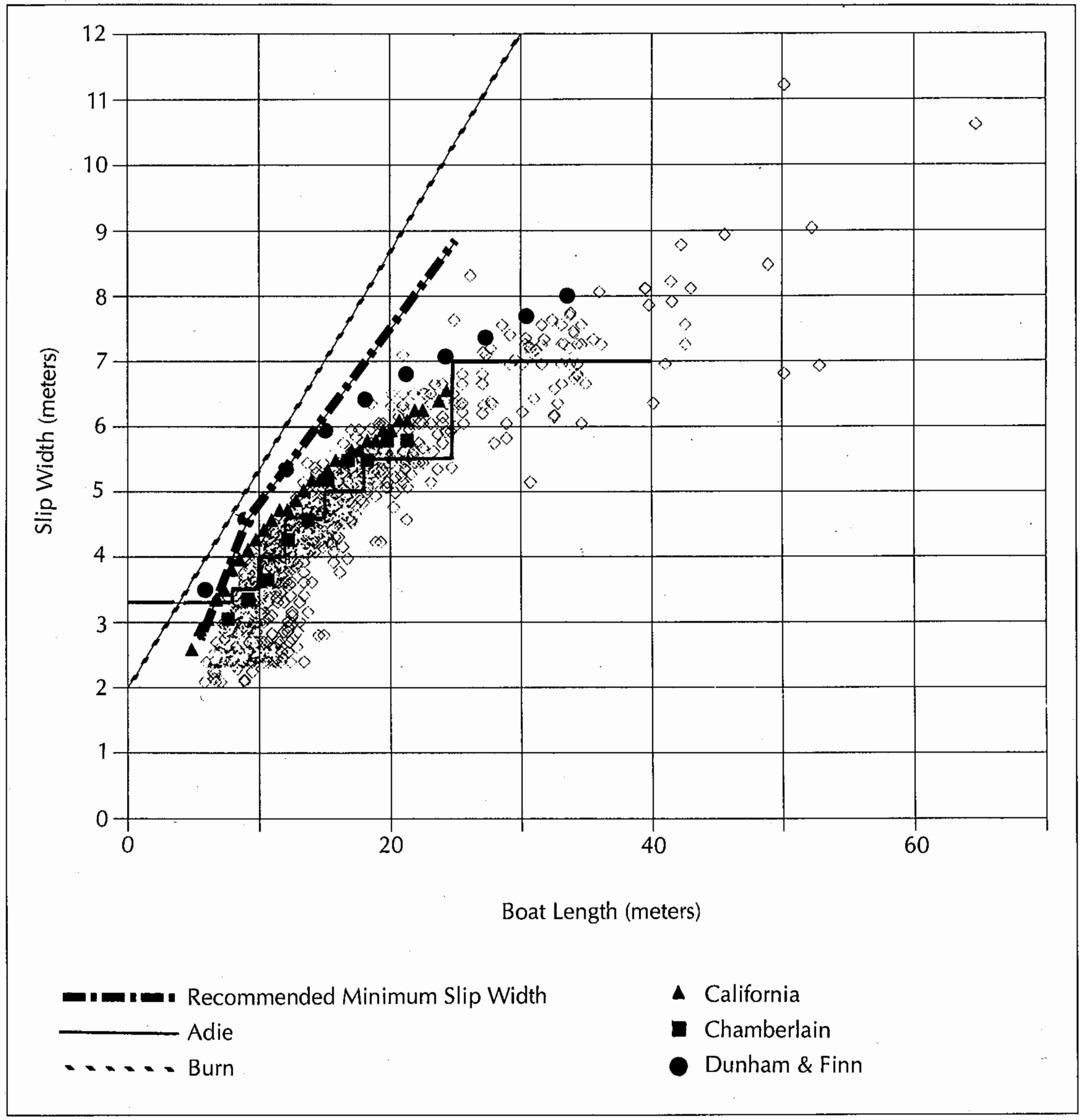

FIGURE 7. A comparison of powerboat slip width guidelines.

with marina design guidelines published in the last two decades? Several existing marina slip width guidelines have been superimposed over the updated beam data as shown in Figures 7 and 8. The beam of many boats is greater than the clear slip width suggested by some of the earlier guidelines, particularly for boats over 17 m (56 ft). Burn,[1] and Dunham and Finn,[5] provide exceptions. The powerboat slip width line by Burn[1] gave no upper boat size limit and this line becomes quite conservative for boats over 20 m (66 ft) in length. The slip width guidelines by Dunham and Finn[5] (the earliest guideline shown) still fit the boat data quite well, at least for boats shorter than about 17 m (56 ft). ASCE Manual 50, *Report on Small Craft Harbors,* did not recommend clear slip widths and could not be included in this comparison.[6]

A partial explanation for the poor fit of some of the guidelines may be the use of waterline beam as the slip width criterion, as noted in the marina guideline by the California Department of Boating and Waterways.[3] However, most

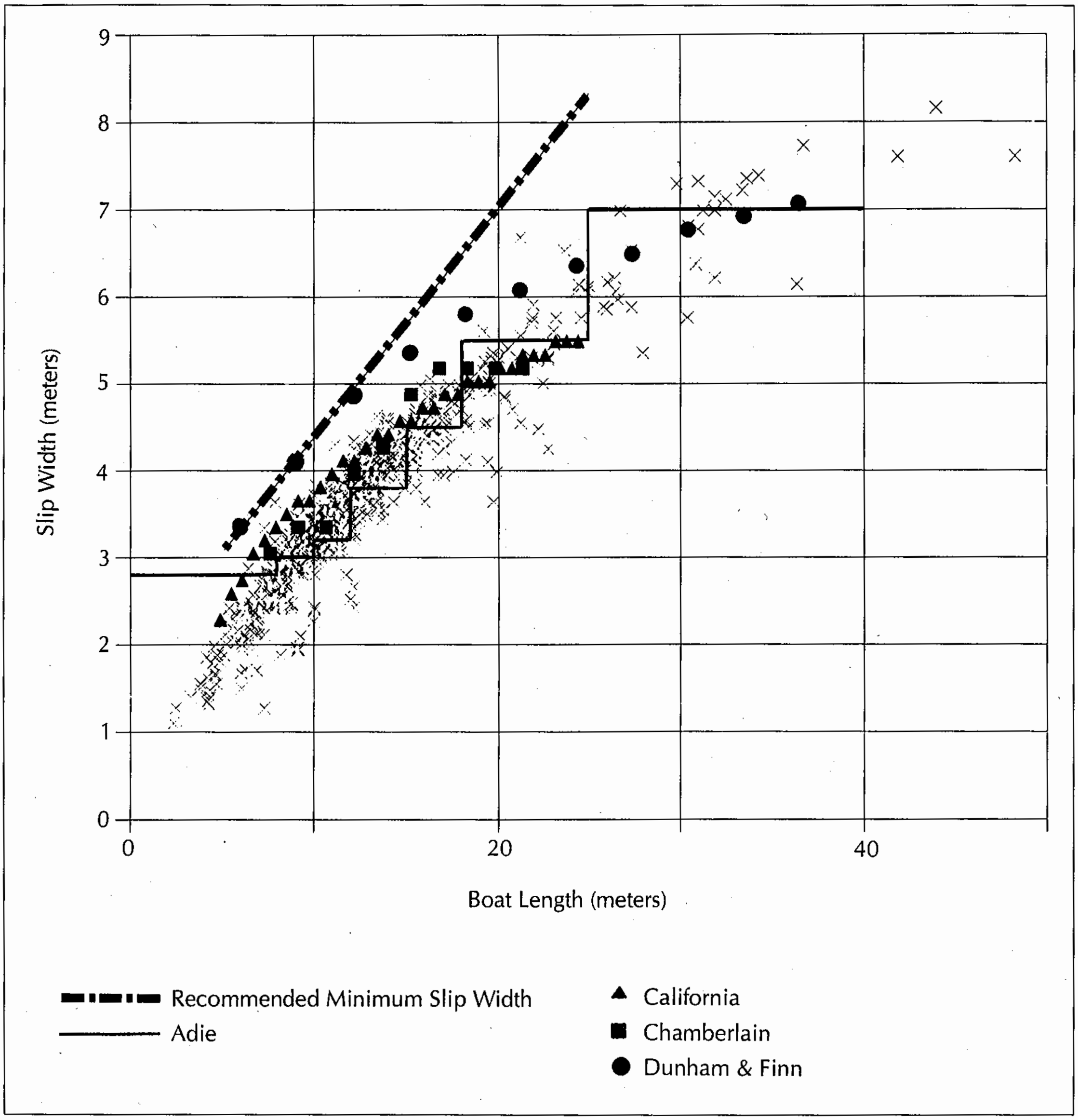

FIGURE 8. A comparison of sailboat slip width guidelines.

commercially manufactured floating dock systems have a dock freeboard 0.5 m (1.7 ft) to 0.8 m (2.6 ft), a height above the waterline where boat beam is very close to its maximum. Most slip width guidelines also assume a constant dimension for width needed beyond the boat beam, to allow for fenders and boat motion. A typical assumption is to add 0.6 m (2.0 ft) to the design beam to account for fenders and allow some space to get in and out of the slip. While this constant of 0.6 m (2.0 ft) might be acceptable for a 10 m (33 ft) boat, it is too tight for large yachts. It is more appropriate to increase slip width above the actual beam as a function of boat size.

Minimum slip width dimensions for an example marina are presented in Table 1 to show how these design recommendations can be applied to marina layout. These dimensions are based on favorable site conditions, with adequate fairway widths, and on the use of a floating dock system. It is also assumed that the example marina will berth a mixture of powerboats and sailboats. Since powerboats gener-

TABLE 1
Example Marina Slip Widths (Based on Powerboat Beams)

Slip Length (meters)	Maximum Beam* (meters)	Clear Single Slip Widths (meters) Recommended	Burn (Ref. 1)	Adie (Ref. 2)	State of California (Ref. 3)	Chamberlain (Ref. 4)	Dunham & Finn (Ref. 5)
9.15	3.81	4.58	5.05	3.50	4.12	3.35	4.56
12.20	4.57	5.39	6.07	4.00	4.42	3.66	4.87
15.24	5.49	6.21	7.08	5.00	5.34	5.18	5.91
18.29	6.00	7.02	8.10	5.00	5.49	5.49	6.11
21.34	7.16	7.84	9.11	5.00	5.64	5.49	6.30

Slip Length (feet)	Maximum Beam* (feet)	Clear Single Slip Widths (feet) Recommended	Burn (Ref. 1)	Adie (Ref. 2)	State of California (Ref. 3)	Chamberlain (Ref. 4)	Dunham & Finn (Ref. 5)
30	12.5	15.0	16.6	11.5	13.5	11.0	15.0
40	15.0	17.7	19.9	13.1	14.5	12.0	16.0
50	18.0	20.4	23.2	16.4	17.5	17.0	19.4
60	19.7	23.0	26.6	16.4	18.0	18.0	20.0
70	23.5	25.7	29.9	16.4	18.5	18.0	20.7

* Maximum boat beam from the database.

ally have the greater beam, the powerboat slip width equation will be used in this example. Note that the slip size increment used in Table 1 is rather large in order to simplify this example.

Included in Table 1 are slip widths from other published marina guidelines in order to illustrate the wide variation in suggested slip width. Average boat beams are also listed from the new database for each boat (slip) length shown. It is evident that slips sized by some of the existing guidelines are too tight for some of the boats that are currently being manufactured.

As planning and design progresses for a specific marina, several site and layout factors must be reviewed. Wind, wave and current conditions should be evaluated under prevailing and extreme conditions. A marina dock alignment should minimize the adverse impact of these site conditions. For example, a boat operator will prefer backing into a slip parallel, not perpendicular to the current and prevailing wind. Wave conditions experienced in a slip should also be considered when setting slip widths. If significant boat motion is anticipated, extra slip width allowances should be made.

Disadvantages do also exist, however, for the oversizing of slip widths. Fewer slips are accommodated in a given water area, and a marina operator can be tempted to put oversize boats in the slips (see Figures 1 and 2). Oversize boats restrict fairway widths, which were designed for smaller boats, and they can overload docks and dock mooring systems.

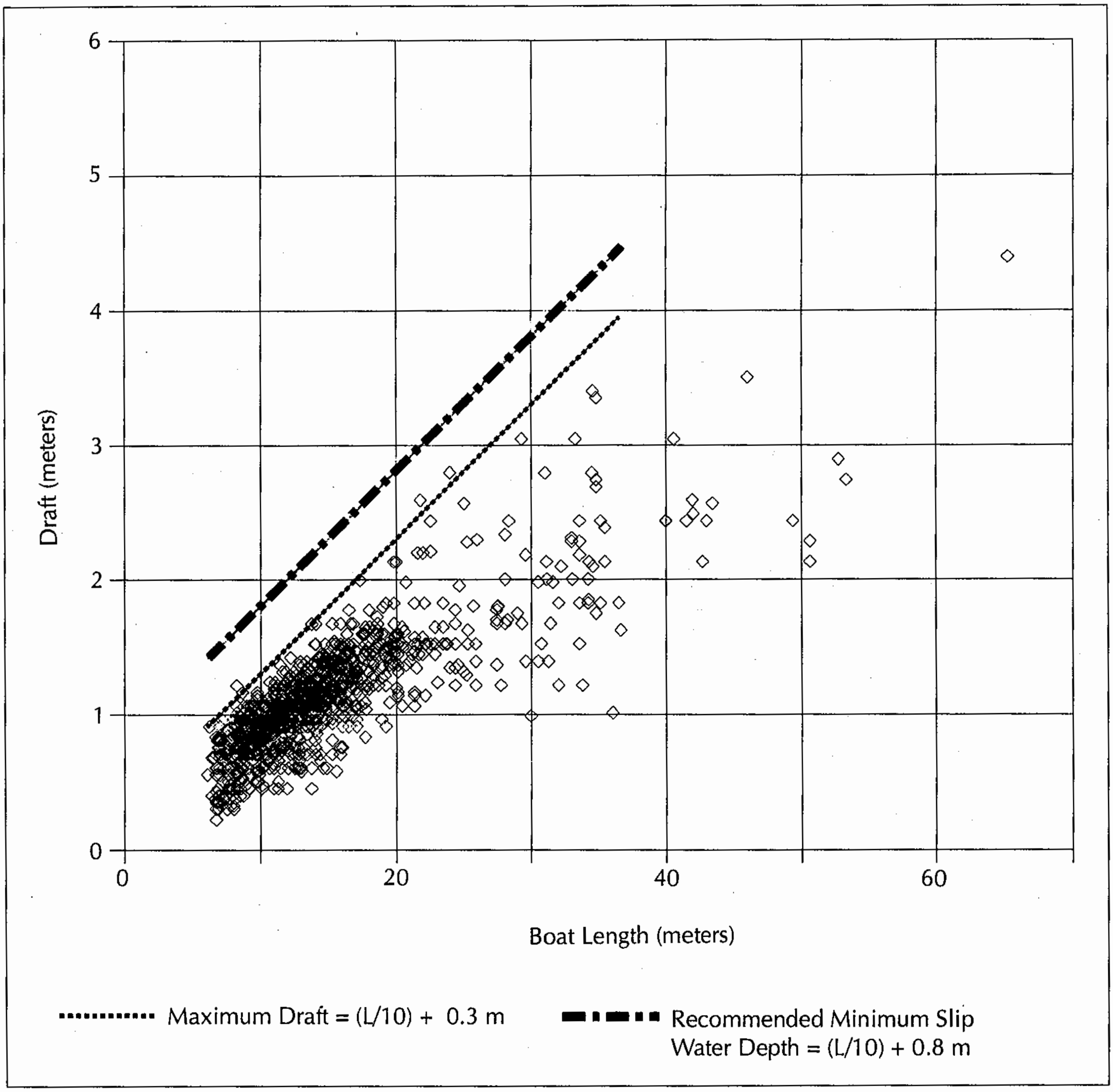

FIGURE 9. A plot of powerboat draft against overall boat length.

Another consideration for setting slip widths is the configuration and type of dock system that will be used. For a double slip dock layout, this recommended clear width would be used for each boat, with an allowance for any piles and stub fingers between the boats, or shared fendering. If double slips are chosen with no separator piles or intermediate stub fingers, then the slip width requirement may be most efficient using the average beam equation with allowance for fenders and maneuvering room. Use of the average beam with double slips assumes that a narrow boat can be berthed with a wide boat.

Some types of floating docks limit the possible slip finger locations and layout flexibility for structural reasons. Other types of floating docks offer a lot of layout flexibility since the fingers can be set to more specific widths in order to closely match the slip widths that are required for each slip size increment. If the dock is fixed, or is supported on piles or posts, the designer may need to allow additional slip width for the floating boat to rise and fall with the tide, lake level or river stage.

Width requirements for dry stack storage and dry stand space are easier to determine

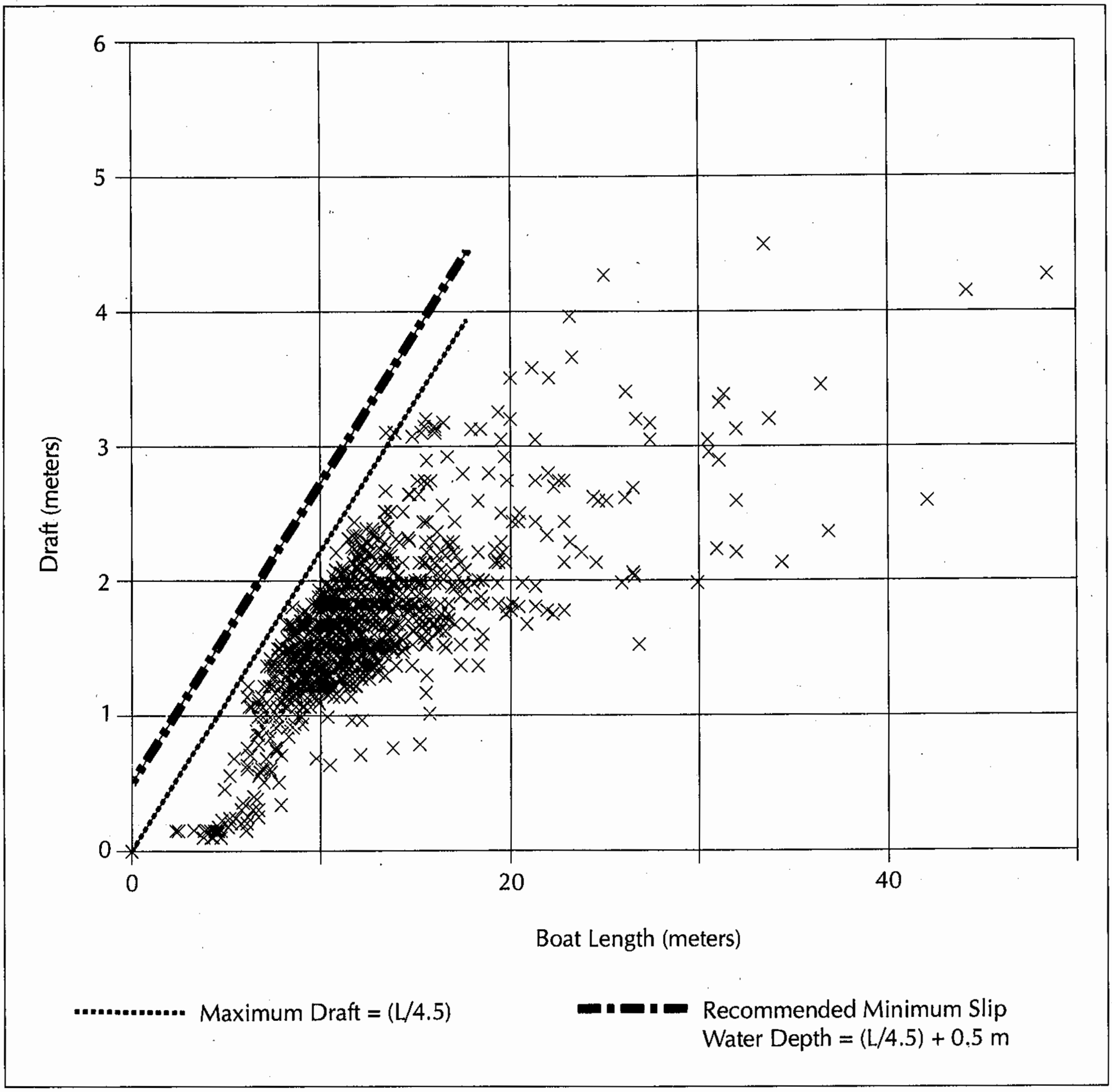

FIGURE 10. A plot of sailboat draft against overall boat length.

than slip widths. Dry storage space is not site or weather specific and the lift operator inserting a boat has good position control. The minimum slip width recommendation is a good place to start estimating clear dry storage width, but it may be possible to use a tighter fit, especially if the storage is long term and the boats are placed by careful lift operators. Like the floating dock systems, it is very helpful to have a dry stack system in which rack spacing can be designed to match the stored boat dimensions. Note that mobile straddle lift boat storage layout is governed by the lift width, and not the boat beam.

Draft

Slip water depth is often as important a marina design criterion as slip width. Dredging an entire marina basin an extra 0.3 m (1.0 ft) deep can greatly increase dredging volume and costs. The regulatory permitting process also may not allow dredging for a new marina. Existing site water depths may control the size and type of boat that can be accommodated.

To develop water depth design criteria, the design draft for many powerboats and sailboats were plotted against overall boat length (see Figures 9 and 10). As expected, there is a lot

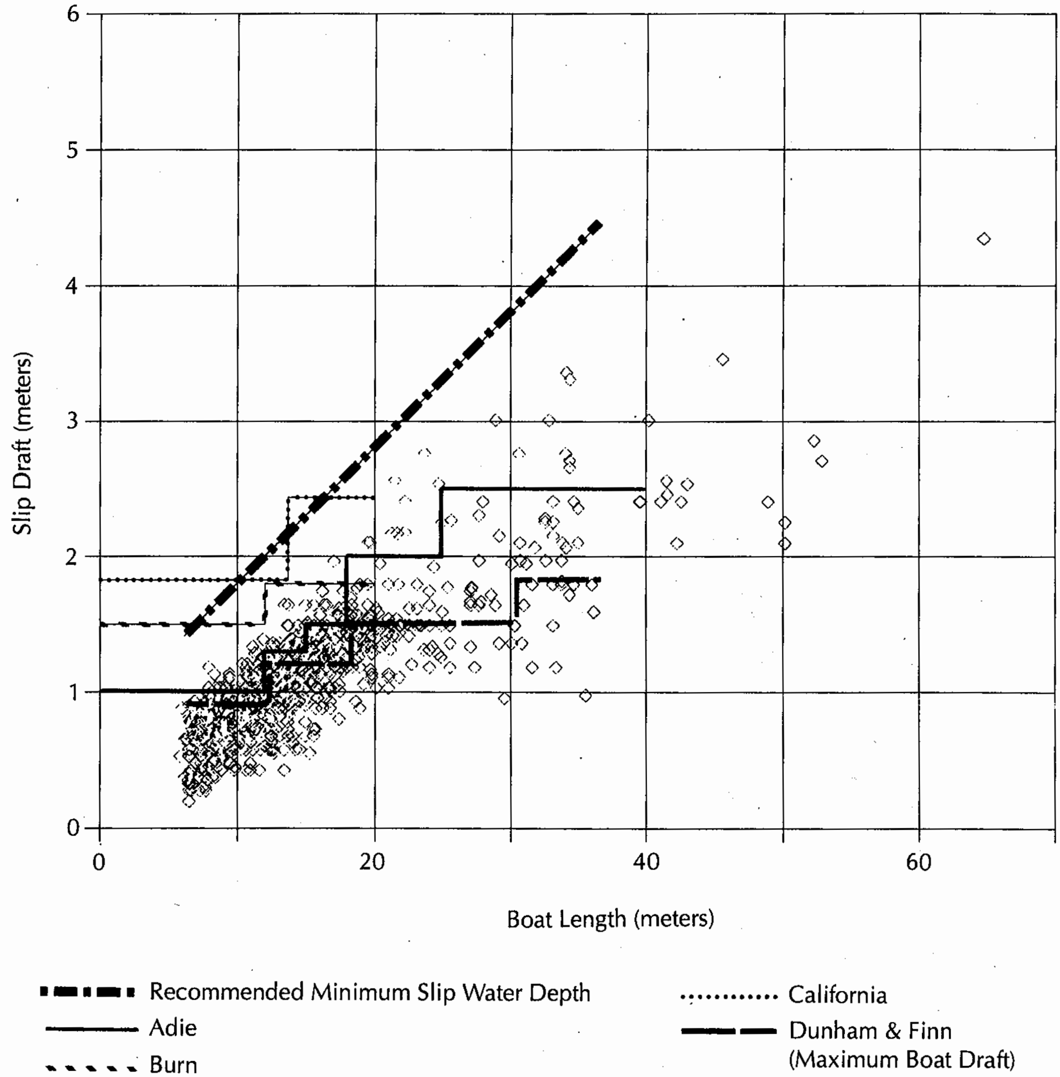

FIGURE 11. A comparison of powerboat slip draft guidelines.

of variation in both powerboat and sailboat drafts. Powerboats of the same length may have displacement type hulls or high-speed, planing type hulls. Sailboats can have several options for the type of keel, such as a centerboard (plotted with centerboard up), shoal draft keel, deep fin keel or wing keel.

Unlike the previous boat beam analysis, an average draft equation is not very useful. The lines fit to these plots represent the maximum boat draft and the recommended minimum slip water depth, allowing half a meter of water under the deepest keels. Sailboats do draw substantially more water than powerboats and in a marina with a mix of boat types, the sailboat drafts will control. For recreational powerboats and sailboats, the upper limit of vessel draft is about 4.5 m (15 ft).

With new depth criteria established, how do they compare to the existing design guidelines? There is a lot of variability between existing guidelines, particularly for powerboat slip water depths (see Figure 11). The powerboat slip water depth guidelines set by the Califor-

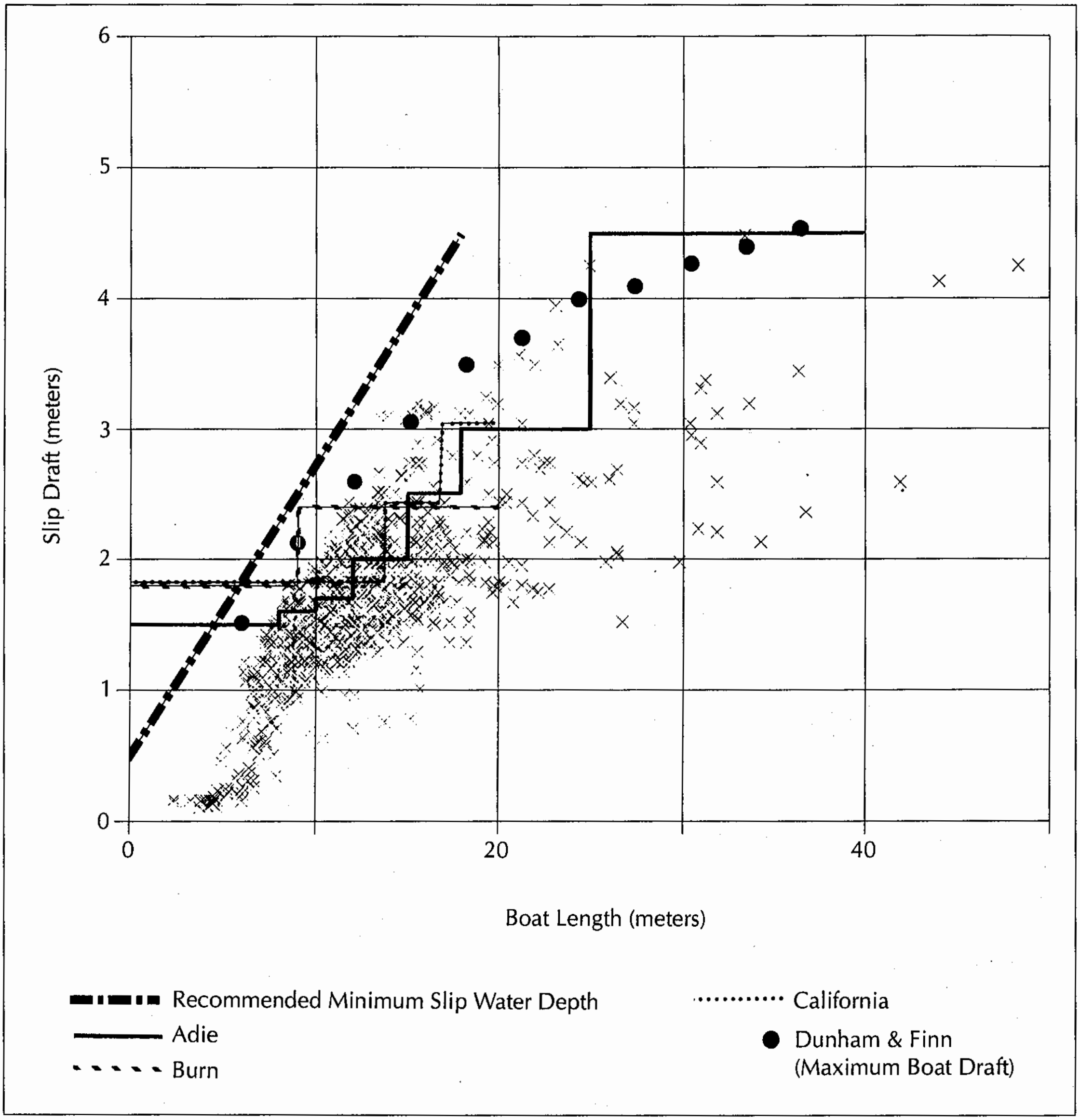

FIGURE 12. A comparison of sailboat slip draft guidelines.

nia Department of Boating and Waterways[3] and by Burn[1] compare well with the latest boat draft data. The powerboat slip water depth guideline by Adie[2] and the maximum powerboat draft guideline by Dunham and Finn[5] are exceeded by a large number of powerboats. These inadequacies may indicate a trend toward deeper draft powerboats, or perhaps only reflect the differences between the boat populations studied (Adie appears to base design criteria only on boats from Europe and the United Kingdom[2]).

Most of the existing guidelines for sailboat slip water depth are exceeded by many of the latest boat drafts, particularly for sailboats over 10 m (33 ft) (see Figure 12). The maximum sailboat draft guideline by Dunham and Finn[5] is an exception. It still fits these new sailboat data very well, while more recent guidelines do not.

Layout criteria for the example marina presented in the last section are expanded to include basin water depths, as shown in Table 2. This table presents maximum slip draft, based

TABLE 2
Example Marina Slip Drafts (Based on Sailboat Drafts)

Slip Length (meters)	Maximum Draft* (meters)	Slip Drafts (meters) Recommended	Burn (Ref. 1)	Adie (Ref. 2)	State of California (Ref. 3)	Dunham & Finn** (Ref. 5)
9.15	1.78	2.53	1.80	1.60	1.83	2.74
12.20	2.34	3.21	2.40	2.00	1.83	3.20
15.24	3.10	3.89	2.40	2.50	2.44	3.66
18.29	3.20	4.50	2.40	3.00	3.05	4.12
21.34	3.58	4.50	2.40	3.00	—	4.33

Slip Length (feet)	Maximum Draft* (feet)	Slip Drafts (feet) Recommended	Burn (Ref. 1)	Adie (Ref. 2)	State of California (Ref. 3)	Dunham & Finn** (Ref. 5)
30	5.8	8.3	5.9	5.2	6.0	9.0
40	7.7	10.5	7.9	6.6	6.0	10.5
50	10.2	12.8	7.9	8.2	8.0	12.0
60	10.5	14.8	7.9	9.8	10.0	13.5
70	11.8	14.8	7.9	9.8	—	14.2

* Maximum boat draft from the database.

** Maximum sailboat draft plus recommended two-foot minimum clearance.

on sailboat drafts controlling the design, for each slip size increment. The proposed basin depths are also selected from several existing marina design guidelines for comparison.

These minimum recommended slip water depths would be applied to the operational extreme low water level expected in a marina basin from spring tides or lake level variations. Experience and good engineering judgement should also be applied to any marina design.

The minimum slip water depth may have to be adjusted to account for site wave action, high sediment accumulation rates, dredging cost and disposal site capacity, ease of future maintenance dredging, type of bottom (soft versus hard), boat type and mix, boat tolerance to grounding, basin flushing and water quality, and the type and cost of dock mooring or support. Note that water can also be too deep for marinas. The cost of dock mooring systems increases rapidly with water depth. Often, water over 10 m (33 ft) deep will make dock moorings prohibitively expensive.

Displacement

Boat displacement, or weight, is not usually used in marina layout, but it is valuable in various design calculations. Uses for displacement values include the design or sizing of boat dry racks, boat forklift trucks, mobile lifts, boat cranes, vertical lift platforms, marine railways and drydocks. Other uses include the analysis of boat berthing energy for fender and dock design, and evaluation of soil and pavement

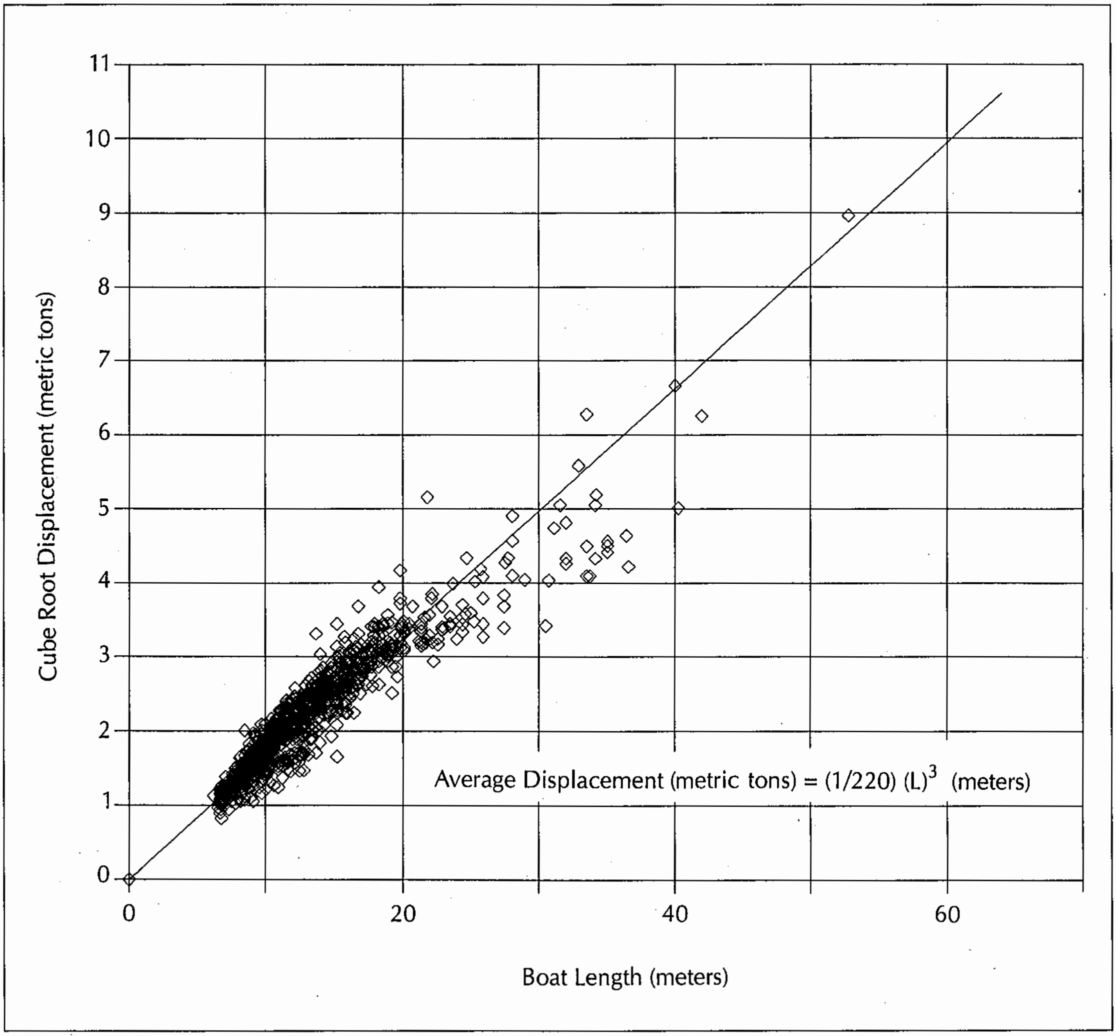

FIGURE 13. The cube root of powerboat displacement *versus* overall boat length.

loads during boat transport and dry storage.

The boat databases were manipulated to identify relationships between boat displacement and overall length. Best-fit power equations were utilized for the powerboat and sailboat displacement data. These power equations met the lower boundary condition of zero displacement at zero boat length, and were found to be very close to cube functions, as expected from dimensional homogeneity. To make a more useful marina design graphic, these data were replotted as shown in Figures 13 and 14, with the cube root of displacement plotted versus overall length. An interesting result was that a typical sailboat is now only slightly heavier than a typical powerboat of the same overall length. This weight equivalence may be the result of recent yacht design trends toward light and ultra-light displacement sailboats and a desire to pack more amenities into a given length of powerboat.

The displacement data were typically obtained from catalogs and represent the boats in a dryship condition, with no water or fuel onboard. To determine the full boat loads, it will be necessary to add allowances for the weight of onboard water, fuel and ancillary equipment. Additional equipment usually accumulates on boats and can significantly increase boat weight. For long-term storage, boats will often have full fuel tanks to minimize water condensation inside the tanks. Similarly, fire

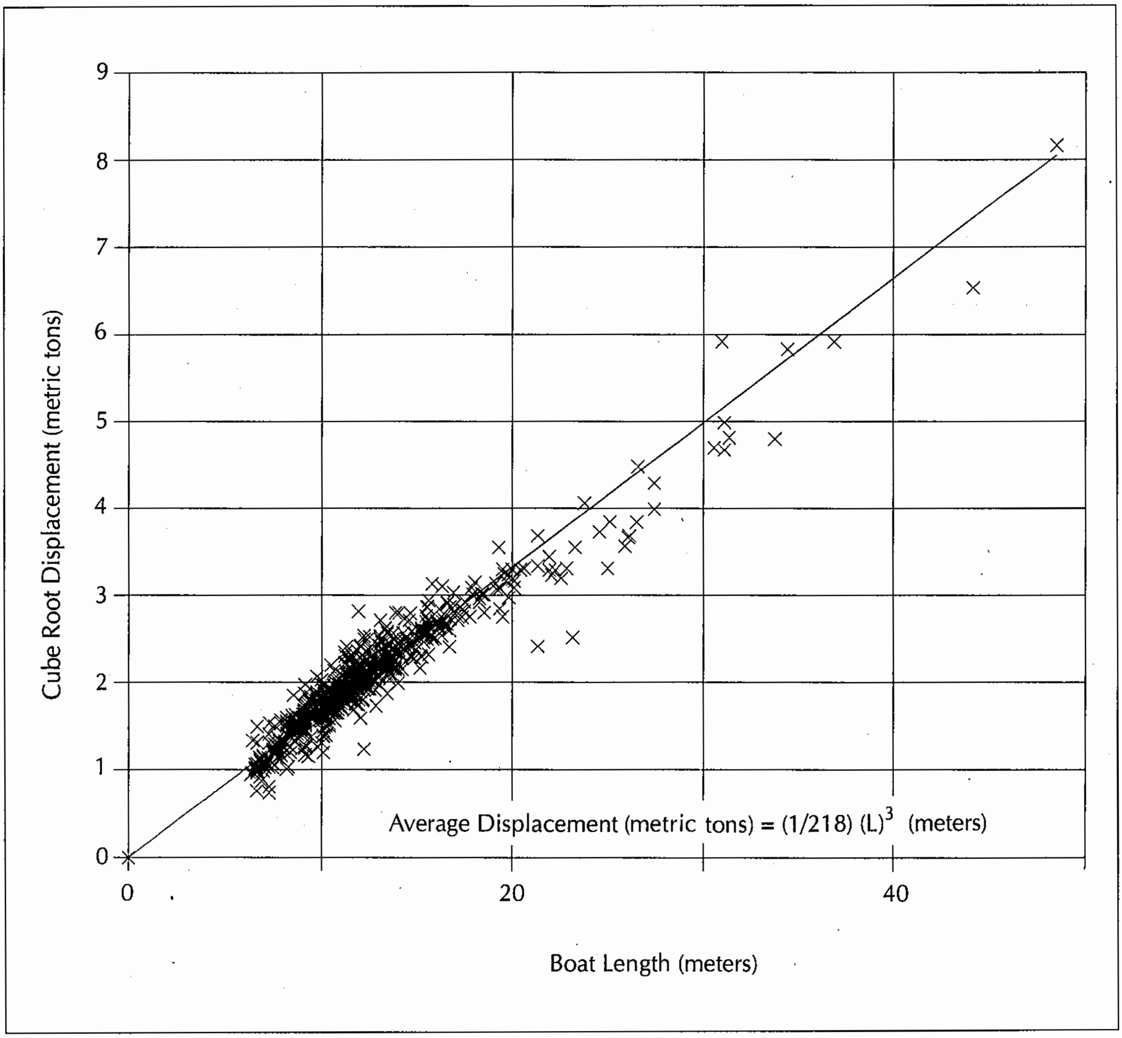

FIGURE 14. The cube root of sailboat displacement *versus* overall boat length.

prevention codes typically recommend that boat fuel tanks be nearly full for dry stack storage.

Conclusions

This comparison of published marina design guidelines with the layout guidelines recommended here has revealed that some of the most recent guidelines have the poorest fit to the updated boat beam and draft data, particularly for boats longer than 16 m (52 ft). The layout guidelines presented here offer a good planning and design tool for marinas. From these guidelines, it is suggested that dimensional adjustments be made in order to account for site specific conditions. Important factors include the selection of floating or fixed dock construction, site exposure, slip size increments, boat type mix and intended market. Marinas types also vary from small homebuilt operations with few boats, to yacht clubs, public and community marinas, and upmarket resorts. Each of the marina types can have very different berthing priorities and users, which should be reflected in layout and design.

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