5. INLAND NAVIGATION CRITERIA

General design requirements for inland navigation channels and lock dimensions are governed by a number of factors, including types and volume of probable future tonnage, types and sizes of vessels and tows in general use on connecting waterways, and developments on other waterways that may indicate the type and size of equipment likely to use the new waterway during its project life. It is important that channel dimensions be adequate to handle the traffic projected to use the waterway. U.S. Army, Corps of Engineers guidance (1980) for channel dimensions states that:

In determining the channel size, some of the basic criteria used are the sectional area ratio, draft-depth ratio, and maneuverability requirements. Tests have indicated that the resistance to tow movement in a restricted channel decreases rapidly as the sectional area ratio (ratio of the channel area to the submerged tow area) is increased to a value of 6 or 7 and then decreases less rapidly as the ratio is further increased. Resistance to tow movement and power required to move the tow are increased if the draft is more than about 75 percent of the available depth, particularly if the channel has restricted width, such as a canal or a lock.

Hydraulic conditions at sites tentatively identified for lock construction should be thoroughly investigated in a general river model of the reach with the lock and dam structure in place.

5.1 Minimum Dependable Depth

Dependable project depth is the minimum depth to be provided for traffic expected to use the waterway; it is not the submergence of the vessel or tow. Thus, a" 9-ft channel" provides a dependable minimum depth of water of 9 feet. The majority of inland waterways in the United States have authorized 9-ft channel depths, and because 9 feet is available, except during drought periods, tows are loaded to 9 feet. The locks are designed to accommodate vessels of 9-ft draft.

Minimum depth in a canalized waterway is usually referenced to normal pool elevation, and pool levels should provide project depth and width over all obstructions in the river bed and over the lower lock sill of the next dam upstream. However, in long, narrow navigation pools, where even low discharges cause an appreciable water surface slope, the water surface profile at minimum discharge may be used as the reference plane rather than the pool elevation.

In a pool with only a short length of channel affected by an obstruction, excavation and maintenance of project depth through that reach can result in reducing the required pool elevation. The costs of such excavation should be evaluated in comparison with savings that could be realized in the cost of lands, damages, and construction of a lower dam.

Navigation pool levels should be set to provide a fixed pool elevation with as little variation as possible because stable pool levels enhance reliability of the waterway and simplify development of port facilities. Greater pool stability can be provided with higher dams because high pools are less frequently affected by flood stages.

5.2 Adequate Channel Width

Adequate width for safe, efficient navigation depends on:

a. Channel alignment.
b. Size of vessel or tow.
c. Whether one-way or two-way traffic is to be provided.

If traffic is projected to be light, provision for one-way traffic may be adequate where reaches are relatively straight with good visibility and if passing lanes are provided. A channel for two-way traffic is much safer and permits traffic to move at higher speeds except when meeting or passing.

Minimum channel clearances for one- and two-way traffic in straight reaches are shown in Figure 5.1. In congested reaches with heavy traffic, greater clearances should be provided. The U.S. Army, Corps of Engineers (1980) suggests the minimum channel widths presented in Table 1 be used in straight reaches, with additional width provided in bends. Mathematical ship simulation models are frequently used to evaluate the ease or difficulty of navigating through specific reaches under various channel widths.

A wider channel is required in bends than in straight reaches because vessels and tows take an oblique position with respect to the tangent of the radius of curvature (measured through the center of the tow) in transiting a bend, Figure 5.2. This angle α, termed the drift angle (or deflection angle), varies with:

a. Radius of curvature of the channel.
b. Speed, power, and design of the craft.
c. Wind forces.
d. Whether the tow is empty or loaded.
e. The flow pattern.

The drift angle for downbound tows is larger than for upbound tows, and design of a channel for one-way traffic is, therefore, based on the channel width required in bends for a downbound tow.

Table 1. Recommended channel width

Tow width (feet)	Channel width (feet)	
	Two-way traffic	One-way traffic
105	300	185
70	230	150
50	190	130

5.3 Freedom from Hazardous Currents

Current velocities in the slack-water pools created by navigation dams are lower than in the natural river, and pool elevations are set sufficiently high to provide adequate depth and eliminate hazardous conditions at rapids. However, the locks and dams themselves may create hazards for navigation because:

a. Tows entering and leaving a lock at low velocity have very limited steering power.
b. Spillway releases can cause tows to break up and drift against spillway gates or sink upstream of the spillway.
c. In some cases, hazardous vortices or turbulence may occur in the upper or lower lock approaches due to operation of the filling or emptying systems.

Some restrictions may be required on operation of spillway gates near a lock to reduce hazardous currents. Guide walls and guard walls are usually provided for some distance above and below a lock to permit tows to move along the walls in safety and line up with the lock.

Maximum velocities and maximum channel depth usually occur along the outer (concave) bank of bends, and a lock aligned with the natural deep-water thalweg of the stream will usually be the least expensive. Lock sites in sharp bends and where the structure would deflect a substantial part of the flow from the deep part of the river should be avoided.

5.4 Minimizing Lock Transit Time

Lockages are time consuming and expensive for both users of a waterway and for operators of the locks, and every effort should be made to minimize lockage time in a navigation system. The time required for tows to pass through a lock for lockages in alternate directions (bound upstream, bound downstream, bound upstream, etc.) includes:

a. The time a tow is operating at reduced speed in approaching, entering, and leaving a lock.
b. The time required to break up and reassemble tows made up of too many barges to pass through the lock in one lockage.
c. The time required to close the lower (or upper) lock gates.
d. The time required to operate filling (or emptying) valves.
e. The time required to fill (or empty) the lock chamber.
f. The time required to operate upper (or lower) lock gates.
g. The time required for tow to exit the lock chamber and reach a point where the tow bound in the opposite direction can enter the lock.

Low-lift locks are simpler to design and construct than high-lift locks, but more are needed in a given river reach, and traffic delays are greater. Lockage time is a part of total "trip time," and savings in trip time increases capacity of the waterway. Such savings can be evaluated in monetary terms in the economic analysis. Lockage time can be minimized by:

a. Providing comparatively straight approaches to locks, free from hazardous currents and with adequate sight distance for safe steering.

b. Designing lock filling and emptying systems so as to minimize valve operating time.

c. Providing lock chambers of suitable size for traffic using the waterway to avoid the need for double lockage of a single tow.

d. Minimizing the number of locks in the system.

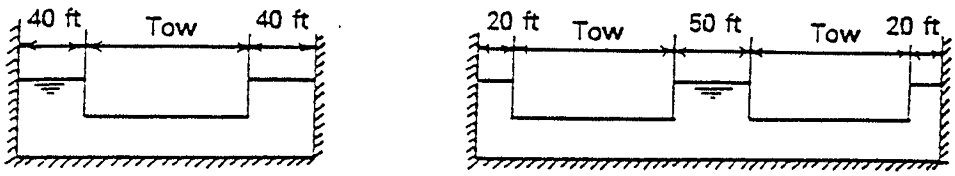
Miter gates can be opened or closed in about one minute; sector gates are operated more slowly if there is filling or emptying around the gate.

5.5 Terminal Facilities

The location of future terminal facilities should be given careful consideration in planning the location of locks and dams for a new navigable waterway. The deep, wide pool immediately above a dam is favorable for development of harbor facilities; however, the pattern of local traffic should be evaluated. Locating a terminal near a lock, either upstream or downstream, may require a large number of lockages for local traffic that will interfere with through traffic.

Factors to be considered in locating new terminals along a canalized waterway include:

a. Will the pool level be relatively stable?
b. Is there existing industrial development that could be served by the waterway?
c. Are there suitable areas nearby for industrial expansion and terminal development?
d. Are there connecting modes of transportation (railroads, highways)?



(a) One-way traffic (b) Two-way traffic

Figure 5.1 Minimum channel clearance in straight reaches. (U.S. Army, Corps of Engineers)

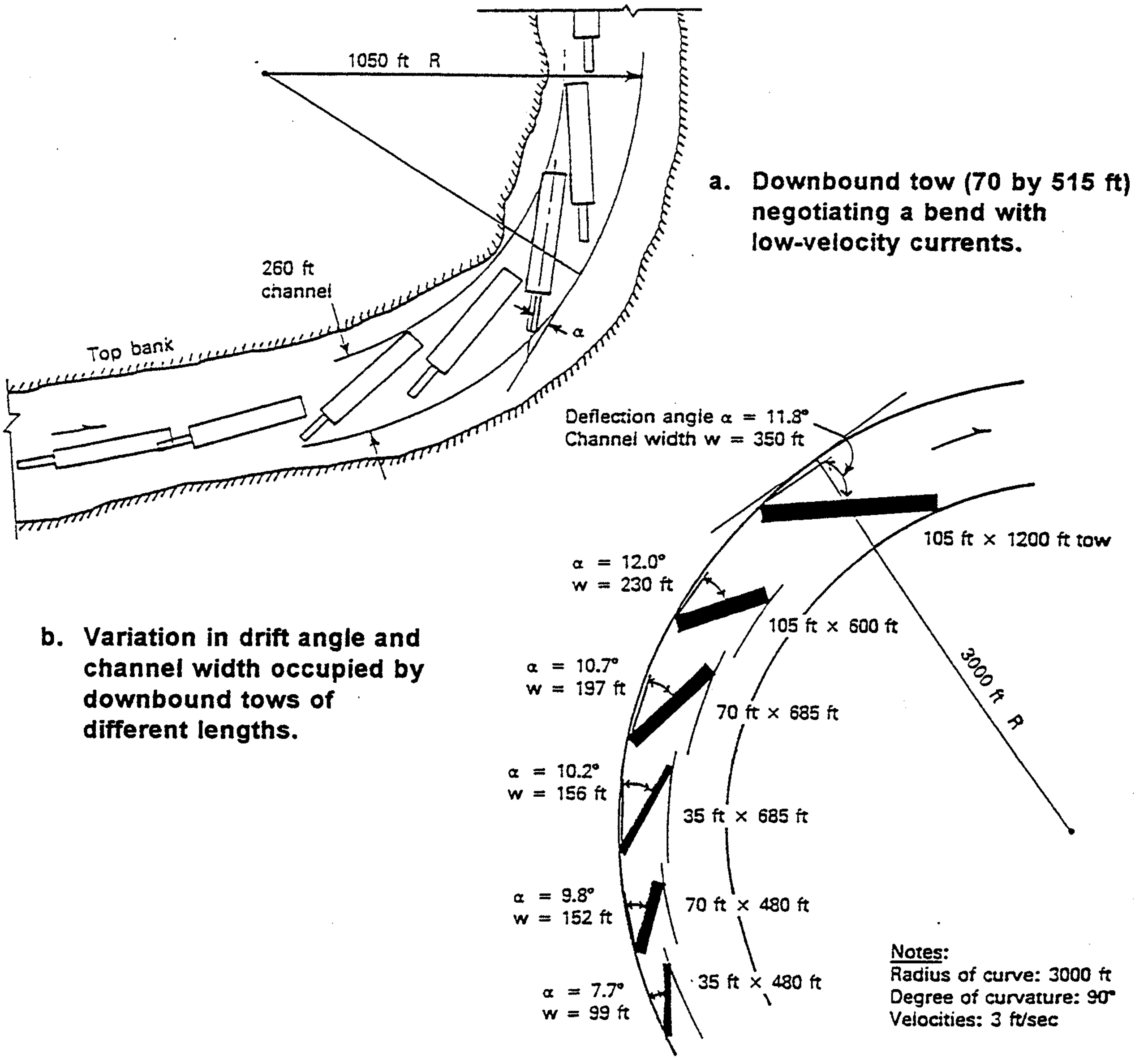


Figure 5.2 Widths required in Bends. (U.S. Army, Corps of Engineers, 1980)