

specific fill/empty times for varying head conditions were used.

Traffic Data

Individual tow sizes were evaluated and grouped into 42 classes. As with the timing information, four year average values (LPMS 1988 -1991), by tow size class, were used in the production of the traffic base. Information for each class consisted of average loads, average number of vessels (upbound and downbound) and, specific to the lock size being studied, the number of cuts that would be required and their dimensions.

Table 5 - 4 displays the 42 towsizes along with their expected frequency and average loads. The 42 towsizes represent approximately 93 percent of the total four-year average number of tows and 89 percent of the tonnage. These figures were adjusted upwards prior to input by proportionally scaling the represented classes to reflect a complete 100 percent traffic base.

Along with tows, information on ship traffic was also compiled. The four year average of ship traffic at the IHNC lock equaled 153 ships. All ship traffic was reflected in a single vessel type.

To capture the effects of stall events on lock operation, stall events were analyzed and represented in the model as a vessel type. Stall events also cause the lock to be unavailable for navigation until the event is concluded. Stall events generally fall into 5 conditions. The first is weather conditions which consist of fog, rain, wind etc. The second is surface conditions consisting of river current, flood, etc. The third is tow conditions consisting of interference by other vessels, tow malfunction or breakdown, etc. The fourth is lock conditions consisting of lock hardware malfunction, maintaining lock, etc. The fifth is Other conditions consisting of vehicular bridge delay (vehicular bridge delays resulting from curfews were separated from bridge delays of other causes because the model explicitly deals with bridge curfews.), tow detained by Coast Guard etc. The four year average for stalls at the IHNC lock was divided into two separate categories in order to provide a more accurate representation of lock downtime. One category consisted of typical stall events which had a four year average of 44 events representing approximately 50 minutes each, while the other category consisted of one outage equal to approximately 30 hours.

Table 5 - 4

Average Number of Tows and Loads
By Tow Size Class

| Tow Size Class | Length (ft) | Width (ft) | Average # Of Tows | Average Tons |
|----------------|------------------|----------------|-------------------|--------------|
| 1 | >=140 and <=223 | >=30 and <=40 | 704 | 205 |
| 2 | >=140 and <=213 | >=41 and <=60 | 216 | 376 |
| 3 | >=224 and <=297 | >=30 and <=40 | 1,306 | 644 |
| 4 | >=214 and <=299 | >=41 and <=60 | 486 | 680 |
| 5 | >=230 and <=319 | >=61 and <=70 | 318 | 812 |
| 6 | >=298 and <=419 | >=30 and <=40 | 250 | 568 |
| 7 | >=300 and <=389 | >=41 and <=60 | 686 | 1,196 |
| 8 | >=320 and <=436 | >=61 and <=70 | 128 | 1,054 |
| 9 | >=420 and <=469 | >=30 and <=40 | 328 | 1,691 |
| 10 | >=390 and <=469 | >=41 and <=60 | 281 | 2,147 |
| 11 | >=437 and <=459 | >=61 and <=70 | 372 | 2,319 |
| 12 | >=470 and <=619 | >=30 and <=40 | 101 | 1,514 |
| 13 | >=470 and <=540 | >=41 and <=60 | 366 | 2,863 |
| 14 | >=460 and <=552 | >=61 and <=70 | 444 | 2,506 |
| 15 | >=620 and <=650 | >=30 and <=40 | 48 | 2,851 |
| 16 | >=541 and <=602 | >=41 and <=60 | 792 | 3,162 |
| 17 | >=553 and <=619 | >=61 and <=70 | 82 | 2,836 |
| 18 | >=603 and <=657 | >=41 and <=60 | 204 | 3,474 |
| 19 | >=620 and <=640 | >=61 and <=70 | 182 | 4,990 |
| 20 | >=641 and <=680 | >=61 and <=70 | 377 | 3,915 |
| 21 | >452 and <=460 | >80 and <=90 | 1 | 3,788 |
| 22 | >355 and <=455 | >91 and <=108 | 62 | 3,619 |
| 23 | =460 | >109 and <=140 | 35 | 5,956 |
| 24 | >470 and <=580 | >80 and <=90 | 5 | 3,096 |
| 25 | >504 and <=580 | >91 and <=108 | 62 | 4,666 |
| 26 | >470 and <=580 | >109 and <=140 | 57 | 6,364 |
| 27 | >585 and <=640 | >91 and <=108 | 186 | 6,144 |
| 28 | >585 and <=640 | >109 and <=140 | 23 | 8,204 |
| 29 | >660 and <=700 | >41 and <=60 | 270 | 3,992 |
| 30 | >681 and <=700 | =70 | 10 | 3,942 |
| 31 | >700 and <=760 | >41 and <=67 | 105 | 4,495 |
| 32 | >700 and <=760 | =70 | 14 | 3,948 |
| 33 | >770 and <=870 | >41 and <=67 | 267 | 4,550 |
| 34 | >770 and <=870 | =70 | 94 | 5,183 |
| 35 | >871 and <=980 | >41 and <=67 | 159 | 5,087 |
| 36 | >871 and <=980 | =70 | 83 | 6,056 |
| 37 | >985 and <=1285 | >41 and <=67 | 101 | 7,568 |
| 38 | >985 and <=1285 | =70 | 91 | 7,441 |
| 39 | >527 and <=627 | =156 | 36 | 7,845 |
| 40 | >660 and <=985 | =140 | 18 | 7,841 |
| 41 | >1286 and <=1530 | =70 | 19 | 10,737 |
| 42 | >1180 and <=1530 | =104 | 3 | 7,775 |

The last category of vessels, other than tows and ships, that need to be considered, is that of light boats. These are towboats that assist other tows requiring multicut lockages. All tows requiring multiple cuts are required to hire an assist vessel to power each additional cut (ready-to-service policy). When the light boat completes its assignment, it then receives priority as it returns to its home base. The Sim model generates a lightboat lockage(s) every time a tow requiring assistance appears at the lock.

The traffic base, therefore, is comprised of 46 separate classes of traffic. Of these 42 are different tow configurations, one is ship traffic, two are stall events and the last is light boat traffic. Each of these classes is assigned a lock priority status, which enables the model to determine the order of service. The highest priority of "0" is assigned to lightboats, the next highest of "1" is assigned to ships, and status "2" represents a general locking policy for all tow classes and stall types. Each of these classes are assigned the appropriate component lockage times from the "lock time table" section of the input file.

Sample Input File

Table 5 - 5 shows a sample input file, representing a without-project condition, used by the Sim model. A brief description is provided alongside each line. Additional discussion is provided for some key inputs.

a. Seed numbers: The three seed numbers specify a chosen starting point for the arrivals generated randomly by the model. The seeds are used for upbound arrival, downbound arrival, and vessel height.

b. Number of Seasons: The model results represent one 90 day season, which is divided into four separate "mini" seasons. The first three "mini" seasons consist of 23 days with the last consisting of 21 days. In addition, an initial warm-up period of ten days was included which allows the model to begin tabulating results from an already operational lock. As will be discussed later, these results are then adjusted upwards to reflect an annual figure.

c. Number of Days Vessel Arrival Data: Initially set at 365 days, the effect of reducing this variable is the same as increasing the traffic level. As was mentioned previously, the 42 tow size classes represent 93 percent of the total vessel traffic, therefore to reflect existing conditions vessel arrival was reduced to 341 days in order

Table 5 - 5

Sim Model Sample Input File
For Without-Project Conditions

```

-----
<lock 640x75<
1
new.seeds
34556833
94727351
1032
100 5
10 23 23 23 999

1

5

QUP 1
999
1

    FLORIDA  999 0

    0
arrival down

STAGE_UP    2
1
1

    CLAIBORNE  .9  0

    0
staging
LOCK_1  3
1

1

    ST.CLAUDE  0  3

    2
    6 45  7 45

    16 30  17 30

** HEADER
** NUMBER OF ITERATIONS
** THE NEXT THREE LINES
SPECIFY AN ARRIVAL PATTERN

** # OF DAYS      # OF SEASONS
** LENGTH OF EACH SEASON
(INCLUDES A WARMUP PERIOD)
** NUMBER OF LOCKS IN THE SYSTEM

** NUMBER OF SEGMENTS IN THE
SYSTEM
** SEGMENT ONE
** QUEUE CAPACITY OF SEGMENT ONE
** NUMBER OF BRIDGES BELOW
SEGMENT ONE
** BRIDGE NAME      % OF TIME BRIDGE DOES
NOT NEED TO BE RAISED      BRIDGE
INTERFERENCE TIME
NUMBER OF CURFEW PERIODS
** SEGMENT TYPE

** SEGMENT TWO
** QUEUE CAPACITY OF SEGMENT TWO
** NUMBER OF BRIDGES BELOW
SEGMENT TWO
** BRIDGE NAME      % OF TIME
BRIDGE DOES NOT NEED TO BE
RAISED      BRIDGE INTER-
FERENCE TIME

** NUMBER OF CURFEW PERIODS

** SEGMENT THREE
** QUEUE CAPACITY OF SEGMENT
THREE
** NUMBER OF BRIDGES BELOW
SEGMENT THREE
** BRIDGE NAME      % OF TIME
BRIDGE DOES NOT NEED TO BE
RAISED      BRIDGE INTER-
FERENCE TIME
** NUMBER OF CURFEW PERIODS
** START AND STOP TIMES OF CURFEW
ONE
** START AND STOP TIMES OF CURFEW

```

lock
 640 75 20
 10.25 10.25 10.0 7.75 7.5
 00.0 15.0 0.0
 5 0

STAGE.DN 4
 1
 0

staging
 QDN 5
 999
 0

arrival up

341

46

1

vtI1 1
 2 1 170 35 205

1 170 35 1

352 352

vtI2 2

2 1 170 54 376
 1 170 54 1

108 108

vtIII1 3

2 1 260 35 644
 1 260 35 3

653 653

vtII2 4

2 1 250 54 680
 1 250 54 3

243 243

vtII3 5

2 1 260 70 812
 1 260 70 5

159 159

vtIII1 6

2 1 335 35 568
 1 335 35 6

125 125

vtIII2 7

2 1 340 54 1196

TWO

** LENGTH OF LOCK WIDTH OF
 LOCK QUEUE SEARCH LIMIT

** CHAMBER TIMES BY SEASON
 (INCLUDES A WARM-UP PERIOD)

** TURNAROUND TIME FOR THE LOCK

** ADDITIONAL TIME FOR
 MULTIVESSEL LOCKAGE

** SEGMENT FOUR

** QUEUE CAPACITY OF SEGMENT FOUR

** NUMBER OF BRIDGES BELOW
 SEGMENT FOUR

** SEGMENT FIVE

** NUMBER OF DAYS VESSEL DATA
 REFLECTS

** NUMBER OF VESSEL CLASSES

** PERCENT OF FULL VESSELS

** VESSEL NAME VESSEL ID

** PRIORITY STATUS HEIGHT

VESSEL LENGTH AND WIDTH

AVERAGE LOAD (TONS)

** NUMBER OF CUTS LENGTH AND
 WIDTH OF CUT LINE ID # IN

LOCK TIMING TABLE

** NUMBER OF DOWNBOUND AND
 UPBOUND OBSERVATIONS

| | | | | |
|---------|----|-----|-----|------|
| | 1 | 340 | 54 | 7 |
| | | 343 | 343 | |
| vtIII3 | 8 | | | |
| 2 | 1 | 350 | 70 | 1054 |
| | 1 | 350 | 70 | 8 |
| | | 64 | 64 | |
| vtIV1 | 9 | | | |
| 2 | 1 | 440 | 35 | 1691 |
| | 1 | 440 | 35 | 9 |
| | | 164 | 164 | |
| vtIV2 | 10 | | | |
| 2 | 1 | 425 | 54 | 2147 |
| | 1 | 425 | 54 | 10 |
| | | 140 | 140 | |
| vtIV3 | 11 | | | |
| 2 | 1 | 450 | 70 | 2319 |
| | 1 | 450 | 70 | 11 |
| | | 186 | 186 | |
| vtV1 | 12 | | | |
| 2 | 1 | 500 | 35 | 1514 |
| | 1 | 500 | 35 | 12 |
| | | 51 | 51 | |
| vtV2 | 13 | | | |
| 2 | 1 | 500 | 54 | 2863 |
| | 1 | 500 | 54 | 12 |
| | | 183 | 183 | |
| vtV3 | 14 | | | |
| 2 | 1 | 490 | 70 | 2506 |
| | 1 | 490 | 70 | 14 |
| | | 222 | 222 | |
| vtVI1 | 15 | | | |
| 2 | 1 | 620 | 35 | 2851 |
| | 1 | 620 | 35 | 12 |
| | | 24 | 24 | |
| vtVI2 | 16 | | | |
| 2 | 1 | 570 | 54 | 3162 |
| | 1 | 570 | 54 | 16 |
| | | 396 | 396 | |
| vtVI3 | 17 | | | |
| 2 | 1 | 575 | 70 | 2836 |
| | 1 | 575 | 70 | 17 |
| | | 41 | 41 | |
| vtVII1 | 18 | | | |
| 2 | 1 | 625 | 54 | 3474 |
| | 1 | 625 | 54 | 18 |
| | | 147 | 147 | |
| vtVII2 | 19 | | | |
| 2 | 1 | 620 | 70 | 4990 |
| | 1 | 620 | 70 | 19 |
| | | 91 | 91 | |
| vtVIII1 | 20 | | | |
| 2 | 1 | 640 | 70 | 3915 |
| | 1 | 640 | 70 | 19 |
| | | 189 | 189 | |

| | | | | | | |
|----------|-----|-----|-----|------|-----|-------|
| vtIX1 | 21 | | | | | |
| 2 | 1 | 456 | 90 | 3788 | | |
| | 2 | 456 | 54 | 10 | 456 | 35 10 |
| | .5 | .5 | | | | |
| vtIX2 | 22 | | | | | |
| 2 | 1 | 405 | 108 | 3619 | | |
| | 2 | 405 | 54 | 10 | 405 | 54 10 |
| | 31 | 31 | | | | |
| vtIX3 | 23 | | | | | |
| 2 | 1 | 460 | 140 | 5956 | | |
| | 2 | 460 | 70 | 14 | 460 | 70 14 |
| | 17 | 17 | | | | |
| vtX1 | 24 | | | | | |
| 2 | 1 | 525 | 90 | 3096 | | |
| | 2 | 525 | 54 | 14 | 525 | 35 15 |
| | 3 | 3 | | | | |
| vtX2 | 25 | | | | | |
| 2 | 1 | 540 | 108 | 4666 | | |
| | 2 | 540 | 54 | 14 | 540 | 54 14 |
| | 31 | 31 | | | | |
| vtX3 | 26 | | | | | |
| 2 | 1 | 525 | 140 | 6364 | | |
| | 2 | 525 | 70 | 14 | 525 | 70 14 |
| | 29 | 29 | | | | |
| vtXI1 | 27 | | | | | |
| 2 | 1 | 610 | 108 | 6144 | | |
| | 2 | 610 | 54 | 18 | 610 | 54 18 |
| | 93 | 93 | | | | |
| vtXI2 | 28 | | | | | |
| 2 | 1 | 610 | 140 | 8204 | | |
| | 2 | 610 | 70 | 17 | 610 | 70 17 |
| | 12 | 12 | | | | |
| vtXIII1 | 29 | | | | | |
| 2 | 1 | 680 | 54 | 3992 | | |
| | 2 | 400 | 54 | 10 | 400 | 54 10 |
| | 135 | 135 | | | | |
| vtXIII2 | 30 | | | | | |
| 2 | 1 | 680 | 70 | 3942 | | |
| | 2 | 400 | 70 | 8 | 400 | 70 8 |
| | 5 | 5 | | | | |
| vtXIII11 | 31 | | | | | |
| 2 | 1 | 730 | 54 | 4495 | | |
| | 2 | 420 | 54 | 10 | 420 | 54 10 |
| | 53 | 53 | | | | |
| vtXIV1 | 32 | | | | | |
| 2 | 1 | 730 | 70 | 3948 | | |
| | 2 | 420 | 70 | 8 | 420 | 70 8 |
| | 7 | 7 | | | | |
| vtXV1 | 33 | | | | | |
| 2 | 1 | 810 | 54 | 4550 | | |
| | 2 | 460 | 54 | 11 | 460 | 54 11 |
| | 133 | 133 | | | | |
| vtXV2 | 34 | | | | | |
| 2 | 1 | 810 | 70 | 5183 | | |

| | | | | | | | | | |
|-----------|-----|------|-----|-------|-----|----|----|-----|----|
| | 2 | 460 | 70 | 14 | 460 | 70 | 14 | | |
| | 47 | 47 | | | | | | | |
| vtXVII1 | 35 | | | | | | | | |
| 2 | 1 | 925 | 54 | 5087 | | | | | |
| | 2 | 520 | 54 | 13 | 520 | 54 | 13 | | |
| | 79 | 79 | | | | | | | |
| vtXVI2 | 36 | | | | | | | | |
| 2 | 1 | 925 | 70 | 6056 | | | | | |
| | 2 | 520 | 70 | 14 | 520 | 70 | 14 | | |
| | 42 | 42 | | | | | | | |
| vtXVIII1 | 37 | | | | | | | | |
| 2 | 1 | 1140 | 54 | 7568 | | | | | |
| | 2 | 620 | 54 | 18 | 620 | 54 | 18 | | |
| | 50 | 50 | | | | | | | |
| vtXVIII2 | 38 | | | | | | | | |
| 2 | 1 | 1140 | 70 | 7441 | | | | | |
| | 2 | 620 | 70 | 19 | 620 | 70 | 19 | | |
| | 45 | 45 | | | | | | | |
| vtXVIII11 | 39 | | | | | | | | |
| 2 | 1 | 575 | 156 | 7845 | | | | | |
| | 3 | 575 | 52 | 12 | 575 | 52 | 12 | 575 | 52 |
| | 18 | 18 | | | | | | | |
| vtXIX1 | 40 | | | | | | | | |
| 2 | 1 | 820 | 140 | 7841 | | | | | |
| | 4 | 465 | 70 | 14 | 465 | 70 | 14 | 465 | 70 |
| | 9 | 9 | | | | | | 465 | 70 |
| vtXX1 | 41 | | | | | | | | |
| 2 | 1 | 1350 | 70 | 10737 | | | | | |
| | 3 | 525 | 70 | 14 | 525 | 70 | 14 | 525 | 70 |
| | 10 | 10 | | | | | | | |
| vtXXI1 | 42 | | | | | | | | |
| 2 | 1 | 1350 | 104 | 7775 | | | | | |
| | 5 | 525 | 70 | 14 | 525 | 70 | 14 | 525 | 70 |
| | 525 | 70 | 14 | | | | | 525 | 70 |
| | .5 | .5 | | | | | | | |
| ships | 43 | | | | | | | | |
| 1 | 1 | 620 | 70 | 0 | | | | | |
| | 1 | 620 | 70 | 22 | | | | | |
| | 72 | 72 | | | | | | | |
| stall1 | 44 | | | | | | | | |
| 2 | 1 | 620 | 70 | 0 | | | | | |
| | 1 | 620 | 70 | 24 | | | | | |
| | 95 | 95 | | | | | | | |
| stall2 | 45 | | | | | | | | |
| 2 | 1 | 620 | 70 | 0 | | | | | |
| | 1 | 620 | 70 | 25 | | | | | |
| | 1 | 1 | | | | | | | |
| lite | 46 | | | | | | | | |
| 0 | 1 | 620 | 70 | 0 | | | | | |
| | 1 | 620 | 70 | 23 | | | | | |
| | 0 | 0 | | | | | | | |
| 25 | | | | | | | | | |
| 1 | 5 | 7 | 4 | 2 | 4 | 5 | 5 | | |

** SHIP TRAFFIC

** STALL EVENT (TYPE 1)

** STALL EVENT (TYPE 2)

** LIGHT BOAT TRAFFIC

** NUMBER OF LINES IN LOCK
TIME TABLE
** LINE ID # LK COMPONENT TIMES

| | | | | | | | |
|----|-----|-----|-----|-----|-----|-----|-----|
| 2 | 6 | 9 | 4 | 3 | 6 | 5 | 8 |
| 3 | 6 | 8 | 4 | 2 | 5 | 5 | 6 |
| 4 | 5 | 9 | 4 | 4 | 5 | 6 | 7 |
| 5 | 7 | 10 | 4 | 4 | 5 | 6 | 7 |
| 6 | 6 | 8 | 4 | 3 | 5 | 6 | 7 |
| 7 | 7 | 9 | 4 | 4 | 5 | 6 | 7 |
| 8 | 8 | 10 | 4 | 4 | 6 | 7 | 8 |
| 9 | 7 | 10 | 4 | 4 | 6 | 7 | 7 |
| 10 | 6 | 9 | 4 | 5 | 6 | 7 | 7 |
| 11 | 7 | 12 | 5 | 6 | 6 | 8 | 8 |
| 12 | 5 | 9 | 4 | 5 | 8 | 7 | 8 |
| 13 | 7 | 10 | 5 | 6 | 6 | 7 | 8 |
| 14 | 7 | 11 | 5 | 6 | 7 | 8 | 9 |
| 15 | 7 | 12 | 5 | 8 | 7 | 7 | 8 |
| 16 | 7 | 8 | 5 | 6 | 7 | 7 | 8 |
| 17 | 8 | 11 | 6 | 8 | 9 | 9 | 10 |
| 18 | 7 | 11 | 5 | 8 | 7 | 8 | 9 |
| 19 | 8 | 10 | 4 | 8 | 8 | 8 | 8 |
| 20 | 0 | 20 | 6 | 9 | 0 | 0 | 19 |
| 21 | 4 | 9 | 5 | 12 | 12 | 12 | 12 |
| 22 | 39 | 12 | 8 | 21 | 10 | 5 | 12 |
| 23 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| 24 | 11 | 11 | 11 | 13 | 11 | 11 | 11 |
| 25 | 605 | 605 | 605 | 605 | 605 | 605 | 605 |

FCFS 0

** SPECIFIES LOCKING POLICY

to proportionally scale upward the represented traffic. It is through use of this value that traffic can easily be scaled up or down to reflect runs of different traffic volumes or utilization levels.

d. Locking Policy: There are two separate locking policies the model will analyze. One represents a first-come, first-serve policy (FCFS), which is the current IHNC locking policy. This simply means that the first tow to arrive at the lock is the first considered for service. The other policy is a n-up n-down policy, which specifies how many tows in one direction will be processed before tows in the opposite direction are processed.

MODEL OUTPUT

Table 5 - 6 displays the various information the Sim model produces as its output for without-project conditions at capacity. Under the heading of "Delay Information", the average delay per tow estimates for the initial ten day warm up period and the following four "mini" seasons are presented. As was mentioned earlier, the total average delay per tow figure excludes the warm up period in its calculation. Under the heading of "Vessel Type Data", lockage information for the 42 tow classes are shown in the first 42 "vt types". Information on ship lockages, stalls and light boats are shown in vt 43 through vt 46, respectively. The maximum level of tons processed through the lock is presented under the heading of "Performance Measures". This figure must be annualized and adjusted to correct for the fact that the existing tonnage associated with the 42 tow classes did not fully represent all IHNC tonnage.

DELAY FUNCTION CALCULATION

The delay function used in this analysis is a simple hyperbolic function. The two parameters that define this type of delay function are lock capacity (in terms of tons) and a k-value, which is the average delay per tow at half of lock capacity.

Using the Sim model to calculate lock capacity for a given condition involved a series of model runs with different seed numbers for each. A total of five runs (at existing traffic levels) were made, each resulting in a different average delay per tow estimate. The seed values corresponding to the median delay estimate was then selected to represent a typical tow arrival pattern. Using these seed values, the arrival frequency of traffic was systematically increased until the level of tonnage

Table 5 - 6

Sim Model Sample Output
Without-Project Conditions

Length Of Run 100 days

ARRIVALS

Upward 1641
Downward 1654
Light Boats 588

DELAY INFORMATION

| season | ave.delay (mins) | Q up | Q down | curfew inbound (mins) | curfew outbound (mins) |
|--------|------------------|-------|--------|-----------------------|------------------------|
| 1 | 987.21 | 15.5 | 17.1 | 2.112 | .746 |
| 2 | 3450.91 | 69.1 | 68.9 | 2.287 | .525 |
| 3 | 8346.30 | 93.4 | 146.2 | 2.477 | .477 |
| 4 | 8093.19 | 118.8 | 111.5 | 2.057 | .589 |
| 5 | 5989.70 | 96.8 | 88.7 | 2.340 | .395 |
| TOTAL | 6540.58 | 94.3 | 102.9 | 2.277 | .499 |

Histogram {hist(i) = #vessels, such that i-1 < delay < i, hours}

| | | | | | | | | | | | | | |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 2 | 5 | 5 | 3 | 6 | 8 | 8 | 8 | 3 | 7 | 5 | 8 | 10 | 6 |
| 11 | 12 | 11 | 8 | 6 | 10 | 8 | 12 | 9 | 4 | 17 | 14 | 9 | 3 |
| 5 | 8 | 6 | 6 | 10 | 18 | 14 | 16 | 25 | 11 | 10 | 8 | 15 | 8 |
| 8 | 10 | 13 | 10 | 3 | 11 | 11 | 8 | 18 | 11 | 13 | 17 | 15 | 19 |
| 17 | 15 | 10 | 9 | 10 | 13 | 8 | 10 | 6 | 10 | | | | |

VESSEL TYPE DATA

Unused space in columns
large cut small cut

| Type | proc (hrs) | delay (hrs) | #Arvls | que max | avg | std | max | avg | std |
|-------|------------|-------------|--------|---------|-----|-----|-----|-----|-----|
| vt 1 | 101.36 | 100.58 | 245 | 92 | 470 | 64 | 84 | 0 | 0 |
| vt 2 | 102.32 | 101.59 | 67 | 86 | 220 | 54 | 48 | 0 | 0 |
| vt 3 | 117.90 | 117.15 | 403 | 89 | 380 | 110 | 82 | 0 | 0 |
| vt 4 | 112.40 | 111.72 | 131 | 82 | 390 | 94 | 60 | 0 | 0 |
| vt 5 | 111.95 | 111.26 | 104 | 88 | 380 | 96 | 69 | 0 | 0 |
| vt 6 | 117.30 | 116.52 | 75 | 91 | 305 | 102 | 103 | 0 | 0 |
| vt 7 | 121.83 | 121.14 | 198 | 86 | 300 | 81 | 83 | 0 | 0 |
| vt 8 | 104.19 | 103.49 | 43 | 70 | 290 | 60 | 72 | 0 | 0 |
| vt 9 | 118.09 | 117.34 | 106 | 75 | 200 | 157 | 74 | 0 | 0 |
| vt 10 | 118.19 | 117.52 | 98 | 80 | 215 | 162 | 79 | 0 | 0 |
| vt 11 | 109.47 | 108.76 | 102 | 90 | 190 | 134 | 80 | 0 | 0 |
| vt 12 | 138.38 | 137.63 | 47 | 83 | 140 | 140 | 0 | 0 | 0 |
| vt 13 | 127.42 | 126.77 | 116 | 97 | 140 | 140 | 0 | 0 | 0 |
| vt 14 | 113.08 | 112.39 | 168 | 83 | 150 | 150 | 0 | 0 | 0 |
| vt 15 | 121.70 | 120.94 | 17 | 77 | 20 | 20 | 0 | 0 | 0 |
| vt 16 | 120.64 | 119.96 | 269 | 91 | 70 | 70 | 0 | 0 | 0 |
| vt 17 | 98.58 | 97.80 | 21 | 81 | 65 | 65 | 0 | 0 | 0 |
| vt 18 | 124.87 | 124.15 | 112 | 82 | 15 | 15 | 0 | 0 | 0 |
| vt 19 | 104.28 | 103.57 | 60 | 89 | 20 | 20 | 0 | 0 | 0 |
| vt 20 | 132.58 | 131.89 | 130 | 91 | 0 | 0 | 0 | 0 | 0 |
| vt 21 | 186.03 | 184.90 | 1 | 137 | 184 | 184 | 0 | 0 | 0 |

| | | | | | | | | | | | |
|----|----|--------|--------|-----|-----|-----|-----|----|---|---|---|
| t | 22 | 111.46 | 110.40 | 14 | 109 | 235 | 192 | 74 | 0 | 0 | 0 |
| c | 23 | 121.95 | 120.93 | 10 | 85 | 180 | 161 | 53 | 0 | 0 | 0 |
| vt | 24 | 40.55 | 36.45 | 2 | 48 | 115 | 115 | 0 | 0 | 0 | 0 |
| vt | 25 | 141.05 | 138.46 | 16 | 79 | 100 | 100 | 0 | 0 | 0 | 0 |
| vt | 26 | 114.77 | 113.66 | 26 | 100 | 115 | 115 | 0 | 0 | 0 | 0 |
| vt | 27 | 131.16 | 128.49 | 71 | 102 | 30 | 30 | 0 | 0 | 0 | 0 |
| vt | 28 | 152.97 | 151.79 | 7 | 110 | 30 | 30 | 0 | 0 | 0 | 0 |
| vt | 29 | 123.54 | 119.76 | 95 | 81 | 240 | 190 | 77 | 0 | 0 | 0 |
| vt | 30 | 22.45 | 21.27 | 1 | 23 | 70 | 70 | 0 | 0 | 0 | 0 |
| vt | 31 | 104.06 | 103.08 | 31 | 88 | 220 | 186 | 68 | 0 | 0 | 0 |
| vt | 32 | 209.61 | 208.25 | 1 | 121 | 220 | 220 | 0 | 0 | 0 | 0 |
| vt | 33 | 144.85 | 142.24 | 98 | 83 | 180 | 137 | 74 | 0 | 0 | 0 |
| vt | 34 | 143.30 | 139.12 | 30 | 79 | 180 | 124 | 80 | 0 | 0 | 0 |
| vt | 35 | 112.96 | 111.85 | 48 | 73 | 120 | 120 | 0 | 0 | 0 | 0 |
| vt | 36 | 94.53 | 93.42 | 24 | 70 | 120 | 120 | 0 | 0 | 0 | 0 |
| vt | 37 | 131.51 | 128.13 | 34 | 74 | 20 | 20 | 0 | 0 | 0 | 0 |
| vt | 38 | 110.54 | 109.45 | 29 | 69 | 20 | 20 | 0 | 0 | 0 | 0 |
| vt | 39 | 107.74 | 106.39 | 21 | 70 | 65 | 65 | 0 | 0 | 0 | 0 |
| vt | 40 | 118.89 | 117.03 | 7 | 115 | 175 | 154 | 56 | 0 | 0 | 0 |
| vt | 41 | 92.84 | 91.39 | 7 | 56 | 115 | 115 | 0 | 0 | 0 | 0 |
| vt | 42 | 0. | 0. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| vt | 43 | 35.21 | 34.27 | 47 | 10 | 20 | 20 | 0 | 0 | 0 | 0 |
| vt | 44 | 122.39 | 121.46 | 70 | 87 | 20 | 20 | 0 | 0 | 0 | 0 |
| vt | 45 | 68.07 | 37.39 | 1 | 47 | 20 | 20 | 0 | 0 | 0 | 0 |
| vt | 46 | 61.21 | 60.87 | 588 | 16 | 20 | 20 | 0 | 0 | 0 | 0 |

LOCKAGE INFORMATION - lock 1

| | |
|------------------------------------|------|
| Total number of lockages completed | 3372 |
| Total upbound | 1504 |
| Total downbound | 1536 |

PERFORMANCE MEASURES

| | | |
|-------------------|-----------------------|--------------|
| Throughout (area) | 103445919.00 (season) | 103445919.00 |
| Throughout (tons) | 6539688.00 | 6539688.00 |

HISTOGRAM

{hist(i) = #lockages, such that i-1<#served in lockage<=i}

2420 496 77 43 3

SPATIAL UTILIZATION

| | |
|----------------------------------|-------|
| average utilization of lock area | 71 % |
| std. dev. utilization | 15 %. |

HISTOGRAM {hist(i) = #lockages with i-1<(space utilized/100)<i}

| < 0 | <10 | <20 | <30 | <40 | <50 | <60 | <70 | <80 | <90 | <100 |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|------|
| 0 | 1 | 2 | 22 | 255 | 511 | 827 | 482 | 101 | 838 | 0 |

UNUSED DIMENSION

| | |
|-----------------------|----------|
| average unused length | 83 (ft.) |
| std. dev. | 74 |
| average unused width | 13 |
| std. dev. | 8 |

SOME MORE STATISTICS

average # vessels
checked for each

| | |
|-----------|----|
| lockage | 2 |
| std. dev. | 5 |
| max # | 20 |

average sum of all

| | |
|-------------------------|-----------|
| lengths of vessels/lock | 577 (ft.) |
| std. dev | 125 |
| max length | 1230 |

average sum of all

| | |
|------------------------|-----|
| widths of vessels/lock | 70 |
| std. dev. | 20 |
| max width | 175 |

average sum of all

| | |
|-----------------------|-------|
| areas of vessels/lock | 34039 |
| std. dev | 7294 |
| max area | 44800 |

processed by the lock no longer increased. This point defined lock capacity.

In order to calculate the corresponding k-values, the model was run at various traffic levels below capacity to provide additional points along the delay function. These estimates of tons processed and average delay per tow, along with the specified capacity, were used to calculate the k-value that generated the "best fit" hyperbola to the model values. The "best fit" function is identified as the function that minimizes the sum of the squared differences between the actual model estimates and the specified function estimate. The measure of the fit is referred to as the coefficient of determination or R-squared.

MODEL RESULTS

Table 5 - 7 provides a summary of model results for the with and without-project scenarios at capacity. The table first displays how multivessel lockages vary with lock size. As expected, the larger the lock size, the greater is the percentage of multivessel lockages. In the existing lock results, note that approximately 79 percent of all lockages are single lockages with practically none in the five tow/lock category, whereas in the 1200 x 110 x 36 ft locksize, almost none of the lockages are single lockages and approximately 44 percent are in the five tow/lock (without curfew) category.

The next section in table 5 - 7 displays how multicut lockages vary with locksize. As expected, the model results show that as the lock size increases, the percentage of multicut lockages decreases to the extent that in the 1200 ft length locks, practically all lockages are single cuts.

The Sim model also provides information on surface area utilization for the various lock dimensions. As table 5 - 7 shows, the range of values for surface area utilization is from approximately 71 percent with the existing and 900 x 90 ft locks, to approximately 85 percent with a 1200 x 110 ft lock.

Finally table 5 - 7 displays tons per lockage and capacity estimates for the various lock sizes. In addition, the percentage increase in capacity by removing bridge curfews is also presented along with the average processing time. As is shown, capacity estimates range from a low of 27.6 million tons for without-project conditions to a high of 74.9 million tons for the 1200 ft x 110 ft x 36 ft lock. The impact of removing bridge curfews on lock capacity is

Table 5 - 7
Simulation Summary Statistics
at Capacity

| | 64x75x31.5 | | 900x90x22 | | 900x110x22 | | 900x110x36 | | 1200x90x22 | | 1200x110x22 | | 1200x110x36 | |
|-----------------------------------|----------------|---------------|----------------|---------------|----------------|---------------|----------------|---------------|----------------|---------------|----------------|---------------|----------------|---------------|
| | with curfew | w/o curfew |
| Pct One Tows/Lock | 78.9 | 76.8 | 79.9 | 37.3 | 17.5 | 17.3 | 17.6 | 15.6 | 8.4 | 8.5 | 0.9 | 1.4 | 0.9 | 0.9 |
| Pct Two Tows/Lock | 16.9 | 18.8 | 16.5 | 38.5 | 17.2 | 19.6 | 18.3 | 19.8 | 29.5 | 30.8 | 4.2 | 4.2 | 4.0 | 3.2 |
| Pct Three Tows/Lock | 2.6 | 2.7 | 2.3 | 18.5 | 35.0 | 32.7 | 35.1 | 35.1 | 27.0 | 26.7 | 17.5 | 17.5 | 16.4 | 13.9 |
| Pct Four Tows/Lock | 1.5 | 1.5 | 1.1 | 5.6 | 27.1 | 26.3 | 25.9 | 26.0 | 21.7 | 21.4 | 39.6 | 40.5 | 40.5 | 37.7 |
| Pct Five Tows/Lock | 0.1 | 0.2 | 0.2 | 1.0 | 2.7 | 4.0 | 3.0 | 3.5 | 13.4 | 12.5 | 37.8 | 38.4 | 38.3 | 44.3 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| Avg Tows/Lock | 1.27 | 1.29 | 1.25 | 1.98 | 2.81 | 2.80 | 2.78 | 2.82 | 3.02 | 2.99 | 4.09 | 4.06 | 4.11 | 4.21 |
| Pct Tows 1-cut | 83.4 | 83.4 | 83.4 | 92.4 | 94.3 | 94.4 | 94.1 | 94.8 | 59.9 | 99.9 | 100.0 | 100.0 | 100.0 | 100.0 |
| Pct Tows 2-cut | 16.4 | 16.4 | 16.4 | 7.5 | 5.7 | 5.6 | 5.9 | 5.2 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 |
| Pct Tows 3-cut | 0.1 | 0.1 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Pct Tows 4-cut | 0.1 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| Surface Area Util: | | | | | | | | | | | | | | |
| Pct Util | 71 | 71 | 69 | 70 | 82 | 82 | 82 | 82 | 75 | 75 | 85 | 84 | 85 | 87 |
| Util S.D. | 15 | 15 | 17 | 19 | 12 | 12 | 12 | 12 | 13 | 13 | 9 | 10 | 9 | 7 |
| Unused Length(ft) | 83 | 84 | 94 | 101 | 60 | 64 | 62 | 61 | 74 | 73 | 51 | 52 | 51 | 42 |
| Unused Length S.D. | 74 | 74 | 86 | 107 | 73 | 78 | 76 | 73 | 70 | 73 | 47 | 47 | 47 | 36 |
| Unused Width(ft) | 13 | 13 | 14 | 14 | 5 | 5 | 5 | 5 | 10 | 11 | 5 | 5 | 5 | 4 |
| Unused Width S.D. | 8 | 8 | 9 | 15 | 7 | 8 | 8 | 8 | 12 | 12 | 5 | 5 | 6 | 4 |
| Tons/Lockage | 2,152 | 2,162 | 2,088 | 3,961 | 5,897 | 5,827 | 5,833 | 5,960 | 7,019 | 6,944 | 8,872 | 9,845 | 9,752 | 10,072 |
| Capacity (mil) | 27.6 | 28.8 | 29.6 | 44.8 | 57.0 | 59.4 | 57.0 | 59.2 | 61.3 | 63.6 | 73.5 | 75.7 | 72.3 | 74.9 |
| Pct Capacity Imp w/o Curfew | | 4.5 | | 3.5 | | 4.2 | | 3.8 | | 3.8 | | 3.0 | | 3.6 |
| Average Processing Time (Minutes) | 61 | 58 | 56 | 58 | 68 | 65 | 67 | 65 | 66 | 65 | 69 | 72 | 72 | 74 |

approximately a three to four percent increase for all sizes.

Table 5 - 8 presents lock capacities and k-values for the first-come; first-serve policy associated with each of the lock sizes that were eventually evaluated in the GEM. In addition, the table also shows a corresponding R-squared value for each estimated equation. The R-squared reflects the degree of "fit" between the model calculated tonnage-delay points and the equation fit to those points.

Also displayed in table 5 - 8 are the capacity and k-values for the existing lock operating under the n-up; n-down policy. Equation parameters are shown for n = 3 and n = 5. With a capacity of 27.1 million tons and a k-value of 3.4, 5-up; 5-down is clearly inferior to the existing first-come first-serve policy. For n = 3, capacity is slightly lower (27.2 million tons) compared to the existing locking policy capacity (27.6 million tons) and the k-value for n = 3 is much higher. As a result, the average delay for a given tonnage level is actually higher with n = 3 than with current policy.

In order to visually highlight the relative differences between alternatives, figures 5 - 1 through 5 - 5 are provided. Figure 5 - 1 displays delay functions for the existing lock, with and without bridge curfews, and with a mid-rise St. Claude Avenue Bridge, without bridge curfews. Figures 5 - 2 and 5 - 3 display delay functions for four improved shallow draft locks with and without bridge curfews, respectively. Figures 5 - 4 and 5 - 5 display delay functions for two deep draft locks with and without bridge curfews, respectively.

Table 5 - 8

Delay Function Parameters
Existing And Improved IHNC Lock
(Simulation Method)

| Condition (First-Come;First-Serve) | Capacity (1,000 Tons) | K-Value | R-Square |
|---|--------------------------|---------|----------|
| Existing Lock | 27.6 | 2.05 | 0.8800 |
| Existing Lock New Bridge w/o curfews | 29.6 | 1.05 | 0.9462 |
| Existing Lock w/o curfews | 28.8 | 1.56 | 0.9098 |
| 900 x 90 x 22 w/curfews | 44.8 | 0.60 | 0.9983 |
| 900 x 90 x 22 w/o curfews | 46.3 | 0.36 | 0.9466 |
| 1200 x 90 x 22 w/curfews | 61.3 | 0.42 | 0.9945 |
| 1200 x 90 x 22 w/o curfews | 63.6 | 0.43 | 0.9998 |
| 900 x 110 x 22 w/curfews | 57.0 | 0.51 | 0.9698 |
| 900 x 110 x 22 w/o curfews | 39.4 | 0.50 | 0.9910 |
| 1200 x 110 x 22 w/curfews | 73.5 | 0.44 | 0.9619 |
| 1200 x 110 x 22 w/o curfews | 75.7 | 0.42 | 0.9917 |
| 900 x 110 x 36 w/curfews | 57.0 | 0.67 | 0.9685 |
| 900 x 110 x 36 w/o curfews | 59.2 | 0.48 | 0.9330 |
| 1200 x 110 x 36 w/curfews | 72.3 | 0.40 | 0.9242 |
| 1200 x 110 x 36 w/o curfews | 74.9 | 0.42 | 0.9449 |
| <u>3-Up;3-Down Policy</u> | | | |
| Existing Lock | 27.2 | 2.85 | 0.9344 |
| <u>5-Up;5-Down Policy</u> | | | |
| Existing Lock | 27.1 | 3.35 | 0.9456 |

FIGURE 5 - 1. DELAY FUNCTIONS
EXISTING LOCK

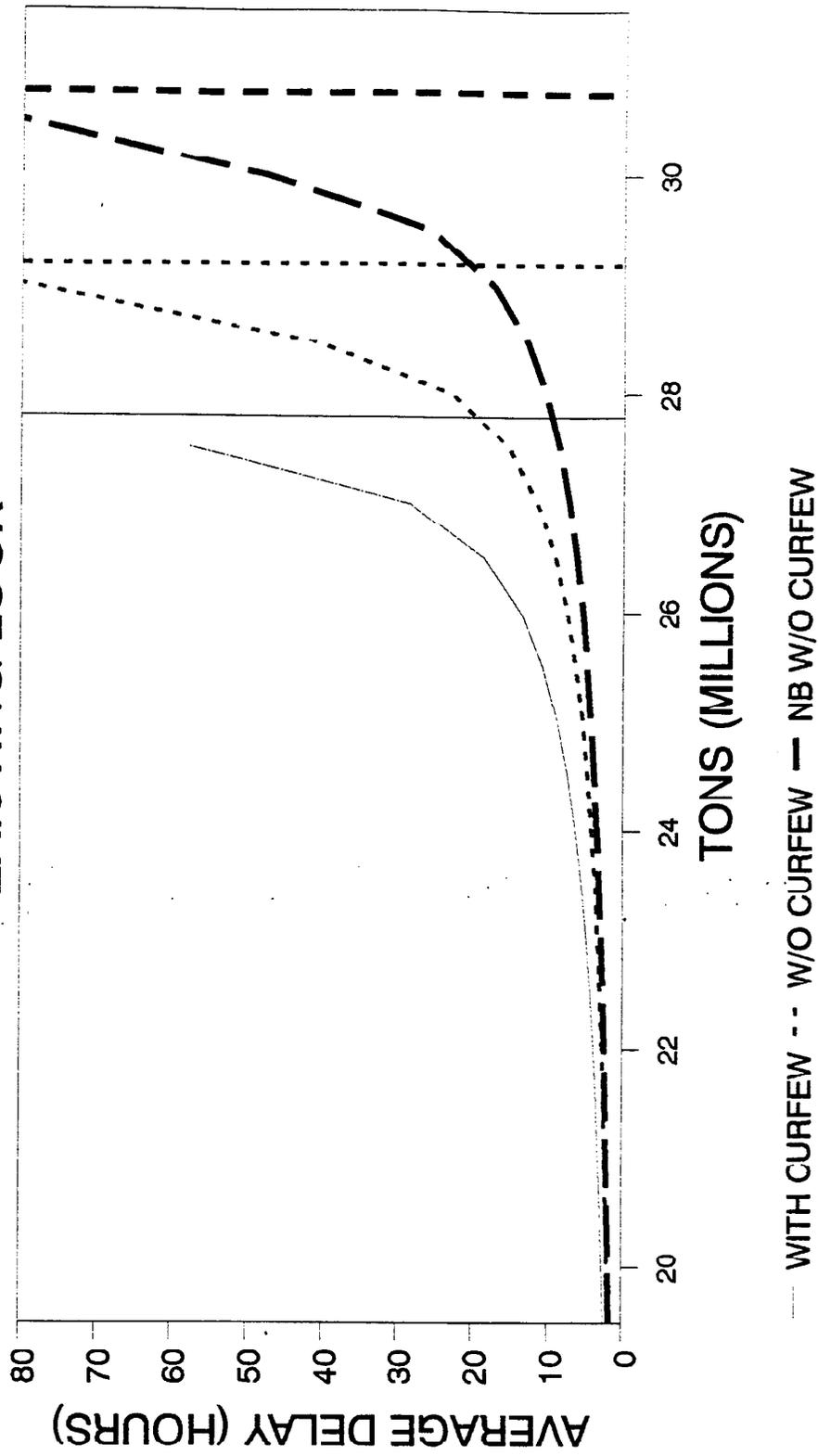
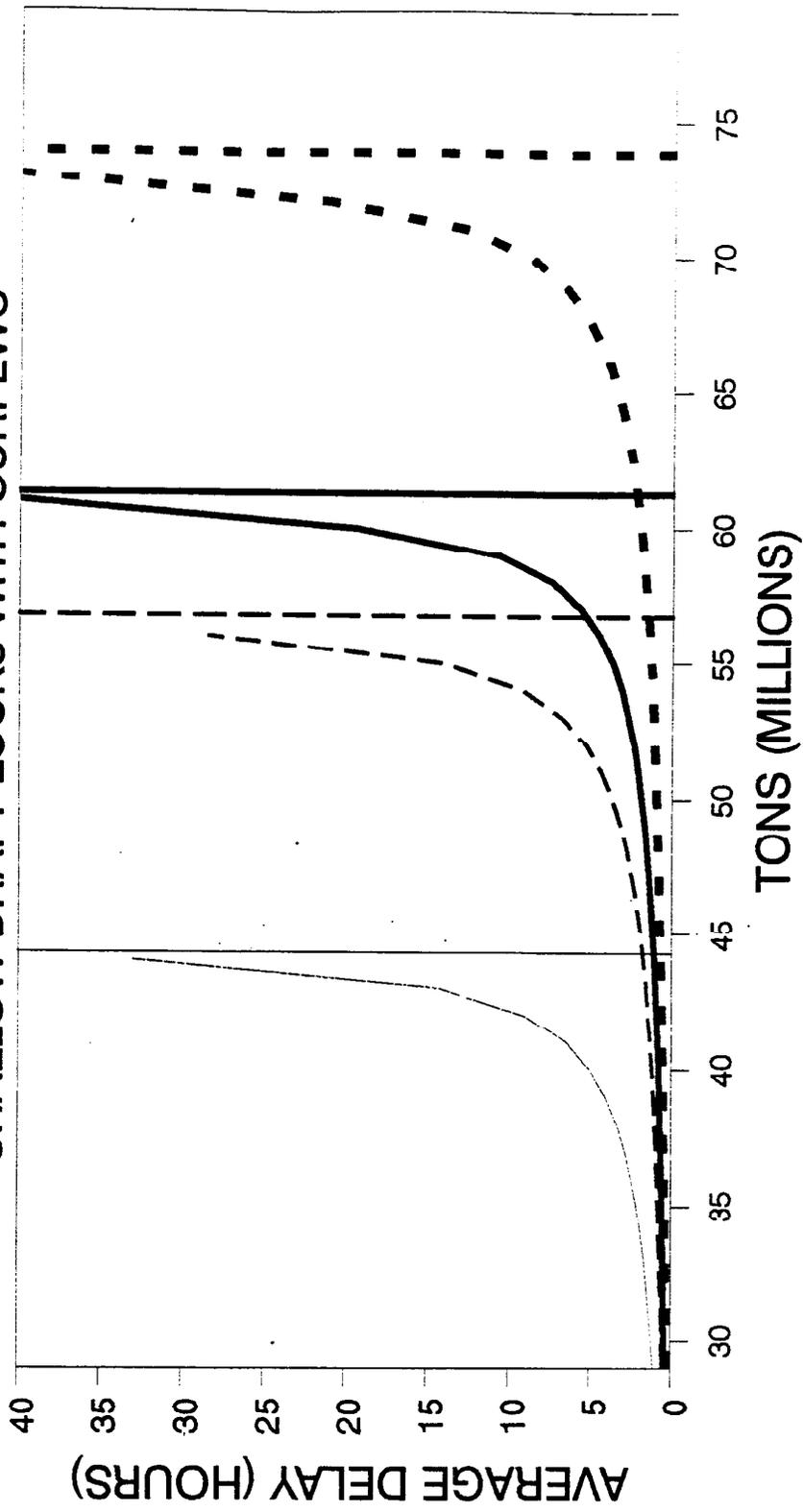


FIGURE 5 - 2. DELAY FUNCTIONS
SHALLOW DRAFT LOCKS WITH CURFEWS



..... 900X90X22 - - - 900X110X22 - - - 1200X90X22 - - - 1200X110X22

FIGURE 5 - 3. DELAY FUNCTIONS
 SHALLOW DRAFT LOCKS WITH NO CURFEWS

