Table 2. Mean (± SD) percent stranded of fish species at each drawdown rate when slope was 1:10. Number of replicates (N) per drawdown rate are stated, and the sample size for each replicate was 10 fish. Shared superscripts indicate that overall means were not significantly different among species using SNK. Standard deviation (SD) for overall means are given in the text.

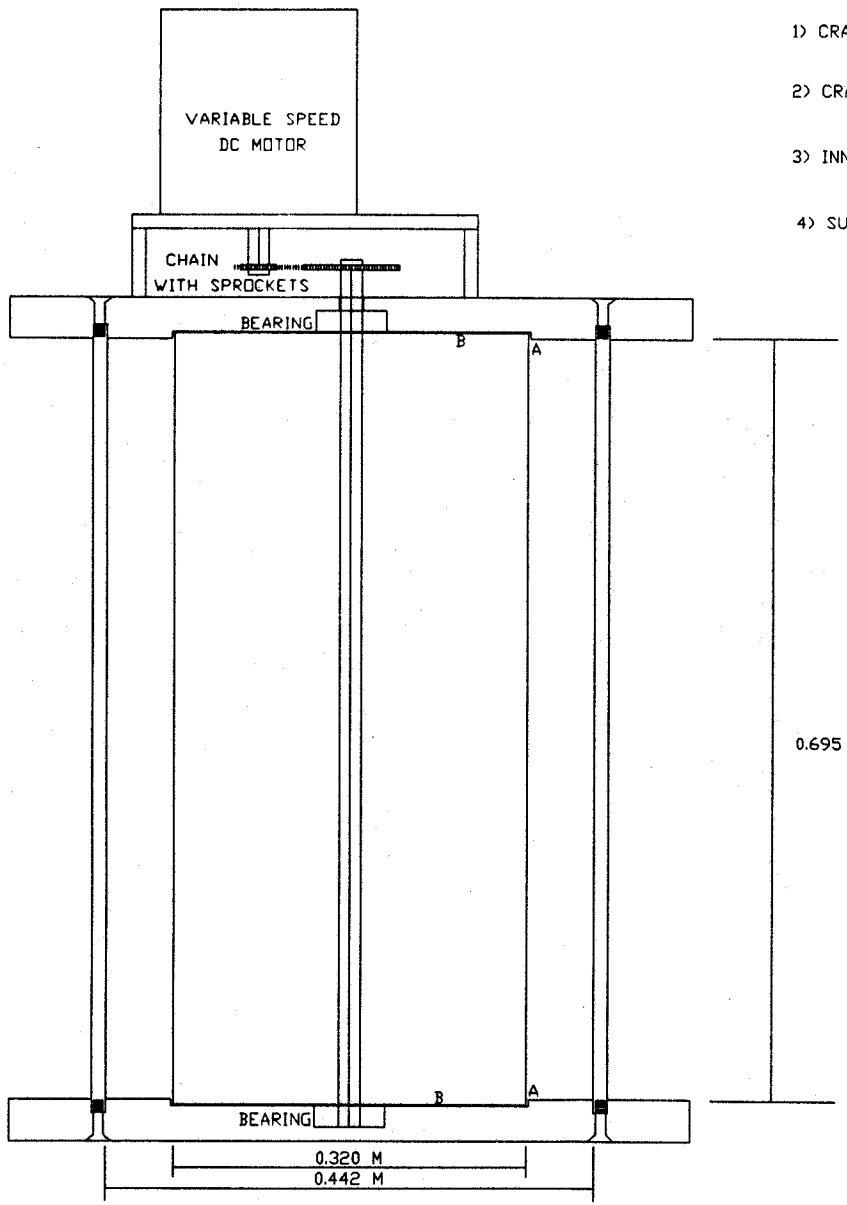
| Species | Drawdown (cm/s) | N | Percent Standed Mean | SD | Overall Mean |
|---|---|---|---|---|---|
| Blue Catfish | 0.76 | 5 | 26.0 | 27.02 | |
| | 0.46 | 5 | 26.0 | 13.42 | |
| | 0.21 | 5 | 28.0 | 19.24 | 26.7[a] |
| Bigmouth Buffalo | 0.76 | 3 | 0.0 | 0.0 | |
| | 0.46 | 3 | 0.0 | 0.0 | |
| | 0.21 | 3 | 0.0 | 0.0 | 0.0[b] |
| Largemouth Bass | 0.76 | 5 | 28.0 | 27.75 | |
| | 0.46 | 5 | 2.0 | 4.47 | |
| | 0.21 | 5 | 16.0 | 15.17 | 15.3[c] |
| Bluegill | 0.76 | 5 | 6.0 | 5.48 | |
| | 0.46 | 5 | 6.0 | 13.42 | |
| | 0.21 | 5 | 4.0 | 5.48 | 5.3[bc] |

1) CRACK A MUST BE SMALLER THAN SMALLEST LARVAE

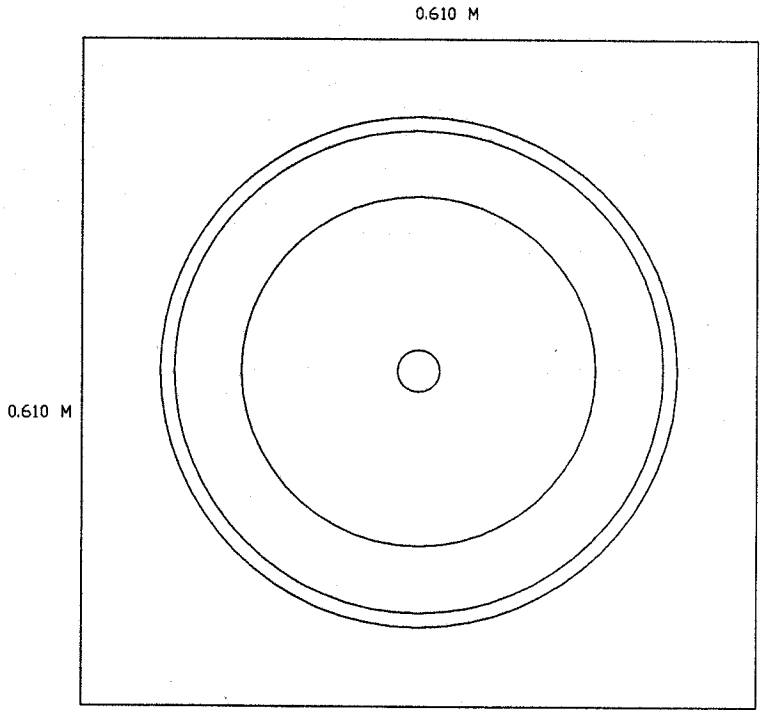
2) CRACK B CAN BE ANYTHING

3) INNER CYLINDER MUST BE WATER TIGHT

4) SURFACES EXPOSED TO LARVAE MUST BE SMOOTH




SIDE VIEW




TOP VIEW

Table 2.-Percent mortality of shovelnose sturgeon Scaphirhynchus platorynchus, bigmouth buffalo Ictiobus cyprinellus, blue catfish Ictalurus furcatus, and largemouth bass Micropterus salmoides at 24 hr and bluegill Lepomis macrochirus at 6 hr exposed to shear levels of 0 (control), 100, 300 or 500 dynes/cm$^2$ for three exposure durations, 30, 60 or 120 sec.

| | Shear Level (dynes/cm$^2$) | | | |
|---|---|---|---|---|
| | Control (0) | 100 | 300 | 500 |
| Exposure Duration (sec) | | | | |
| **Shovelnose sturgeon** | | | | |
| 30 | 3.3 | 0 | 0 | 0 |
| 60 | 3.3 | 0 | 0 | 0 |
| 120 | 0 | 0 | 0 | 0 |
| **Bigmouth buffalo** - Most pelagic compared to other species tested | | | | |
| 30 | 6.7 | 0 | 10.0 | 33.3* |
| 60 | 3.3 | 0 | 23.3* | 20.0 |
| 120 | 3.3 | 6.7 | 26.7* | 66.7** |

250 dynes/cm2
1.22 depth ratio
Equivalent to high speed tow

| | | | | |
|---|---|---|---|---|
| **Blue catfish** | | | | |
| 30 | 0 | 0 | 0 | 0 |
| 60 | 0 | 0 | 0 | 0 |
| 120 | 0 | 0 | 0 | 0 |
| **Largemouth bass** | | | | |
| 30 | 0 | 0 | 0 | 0 |
| 60 | 0 | 5.0 | 0 | 5.0 |
| 120 | 0 | 0 | 0 | 5.0 |
| **Bluegill** | | | | |
| 30 | 0 | 0 | 0 | 3.3 |
| 60 | 3.3 | 6.7 | 0 | 10.0 |
| 120 | 10.0 | 0 | 0 | 56.6** |

* $P<0.05$
** $P<0.01$

Table 3.-Representative shear values (dynes/cm$^2$) for two vessel speeds and two depth/draft ratios.

| Vessel Speed Ratio (m/sec) | Depth/Draft | Exposure Duration (sec) | Representative Shear (dynes/cm$^2$) for percent exceedance | | |
|---|---|---|---|---|---|
| | | | 50 | 10 | 5 |
| 2.9 Typical Velocity | 1.22 | 102 | 87 | 129 | 142 |
| 4.0 | 1.22 | 74 | 135 | 225 | 250 |
| 2.9 | 2.0 | 102 | 53 | 107 | 115 |
| 4.0 | 2.0 | 74 | 57 | 187 | 204 |

Three pressure change regimes were created to simulate fish entrainment and vertical displacement within the propeller wash behind tow boats. All pressure measurements are reported in absolute pressure (gage pressure + atmospheric pressure, 101.3 Kpa STP) unless otherwise stated.

Cycle 1 - Pressure was gradually raised to 446.1 Kpa over 1 h, held for 30 min, and returned to atmospheric pressure in 5 sec.

Cycle 2 - Pressure was raised to 446.1 Kpa within 5 sec, held for 10 sec, and returned to atmospheric pressure in 5 sec.

Cycle 3 - Pressure was raised to 446.1 Kpa within 5 sec, held for 30 min, and returned to atmospheric pressure in 5 sec.

Table 2.-Mortality of experimental and control fish at 1 h, 4 h, and 8 h post-exposure to three pressure change regimes (N=100).

| | Percent Mortality | | |
|---|---|---|---|
| | 1 hour | 4 hours | 8 hours |
| **Bigmouth buffalo** | | | |
| Cycle 1 | 0 | 0 | 1 |
| Control | 0 | 0 | 0 |
| Cycle 2 | 0 | 0 | 3 |
| Control | 0 | 1 | 1 |
| Cycle 3 | 1 | 1 | 1 |
| Control | 0 | 0 | 0 |
| **Blue catfish** | | | |
| Cycle 1 | 0 | 0 | 1 |
| Control | 0 | 0 | 0 |
| Cycle 2 | 0 | 0 | 0 |
| Control | 0 | 0 | 0 |
| Cycle 3 | 0 | 0 | 0 |
| Control | 0 | 0 | 0 |
| **Bluegill** | | | |
| Cycle 1 | 0 | 0 | 3 |
| Control | 0 | 1 | 8 |
| Cycle 2 | 0 | 4 | 5 |
| Control | 0 | 0 | 1 |
| Cycle 3 | 0 | 3 | 7 |
| Control | 0 | 1 | 4 |
| **Largemouth bass** | | | |
| Cycle 1 | 0 | 0 | 0 |
| Control | 0 | 0 | 0 |
| Cycle 2 | 0 | 0 | 0 |
| Control | 0 | 0 | 0 |
| Cycle 3 | 0 | 0 | 0 |
| Control | 0 | 0 | 0 |

Table 3.-Pressures (kPa) experienced by larval fish with depth (m).

| Depth (m) | Absolute Pressure (kPa) @ STP |
|---|---|
| 0 | 101.3 |
| 2.7[1] | 127.8 |
| 3.0 | 130.7 |
| 5.0 | 150.3 |
| 10.0 | 199.3 |
| 20.0 | 297.3 |
| 30.0 | 395.3 |
| 35.2[2] | 446.1 |
| 40.0 | 493.3 |

[1] A 2.7 m navigation channel is maintained by the U.S. Army Corps of Engineers.

[2] A depth of 35.2 m is equivalent to the largest pressure tested during this study.

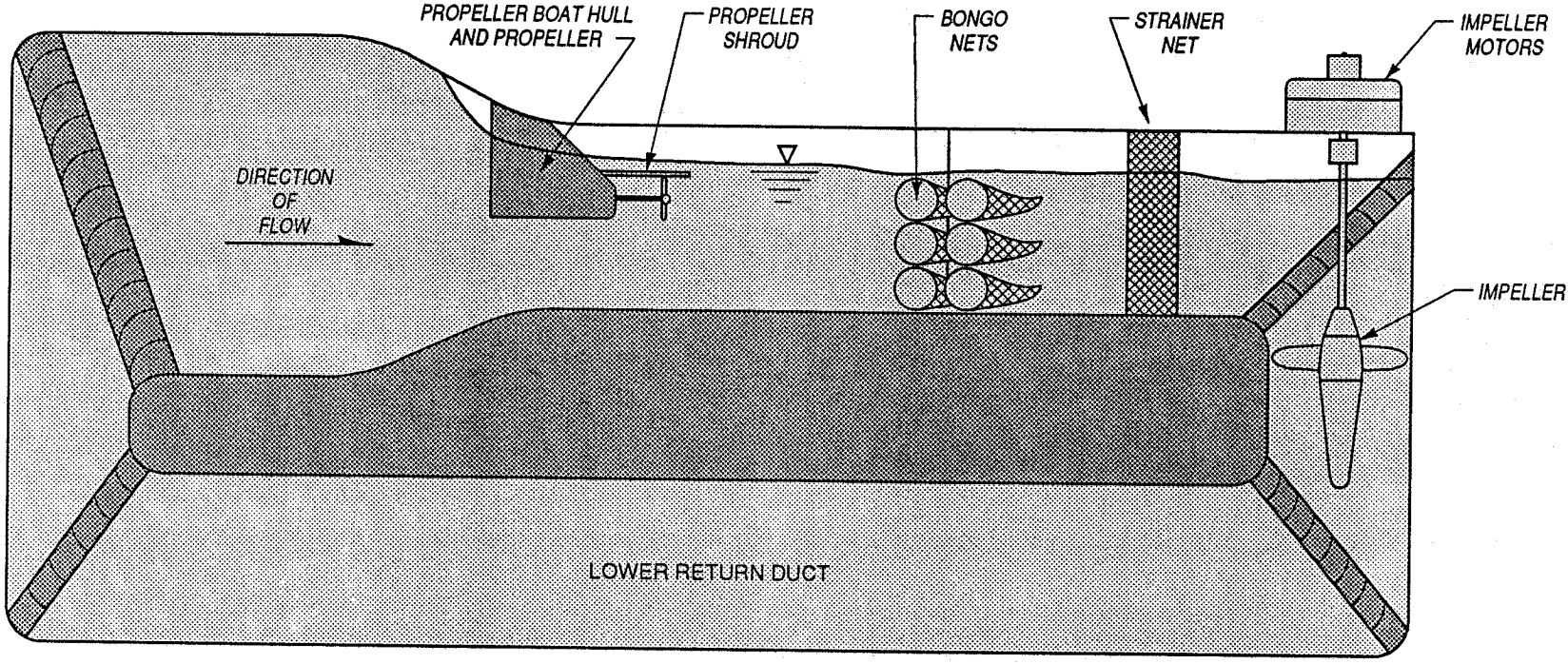


Table 3. Mean percent mortality of fish species entrained through or adjacent to propeller operating at different rotations per minute. Values with different letters along a row are significantly different according to the Student-Neuman-Keuls Multiple Range Test. Probability values represent results of the full model ANOVA.

| Species/Life stage | N | Rotations per Minute 0 | 400 | 598 | 798 | 969 | Probability | $R^2$ |
|---|---|---|---|---|---|---|---|---|
| Control 6x3=18 | | | | | | | | |
| Shovelnose sturgeon larvae | 4x3=12 | $14^a$ | - | - | - | $58^b$ | 0.012 | 0.67 |
| Lake sturgeon larvae | 5 | $2^a$ | - | $23^b$ | $47^b$ | $87^c$ | 0.001 | 0.78 |
| worst case scenario | | | | | | | | |
| Paddlefish eggs | 5 | $15^a$ | - | - | - | $30^b$ | 0.001 | 0.67 |
| Paddlefish larvae | 7 | $15^a$ | $9^a$ | $21^a$ | $40^b$ | $49^b$ | 0.001 | 0.65 |
| Common carp juveniles - through propeller | 5 | $0^a$ | - | $7^b$ | - | $16^b$ | 0.006 | 0.53 |
| Common carp juveniles - beside propeller | 5 | $0^a$ | - | $6^b$ | - | $29^c$ | 0.001 | 0.89 |
| Blue sucker larvae | 3* | 41 | - | 74 | - | 78 | 0.084 | 0.44 |

*Sample size was 3 for all treatments, 6 for controls

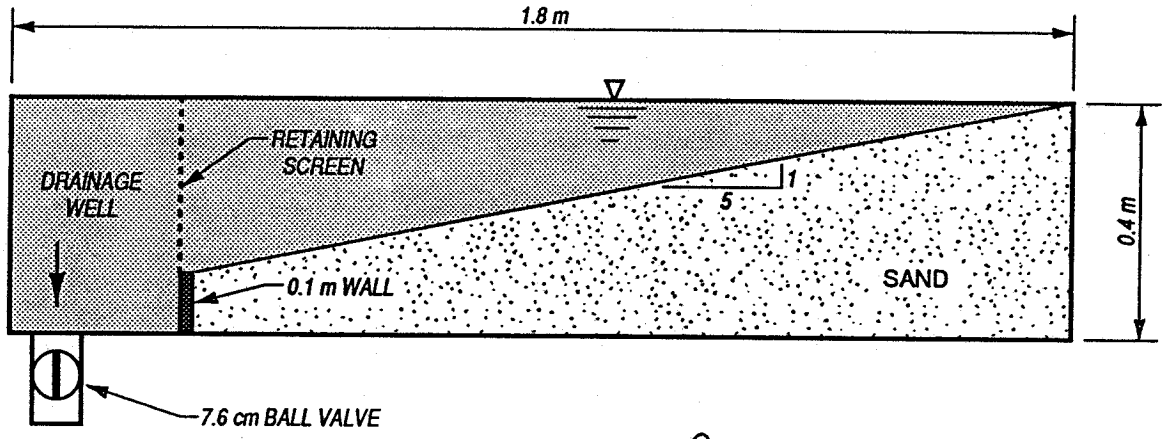
may be reflective of their micro habitats

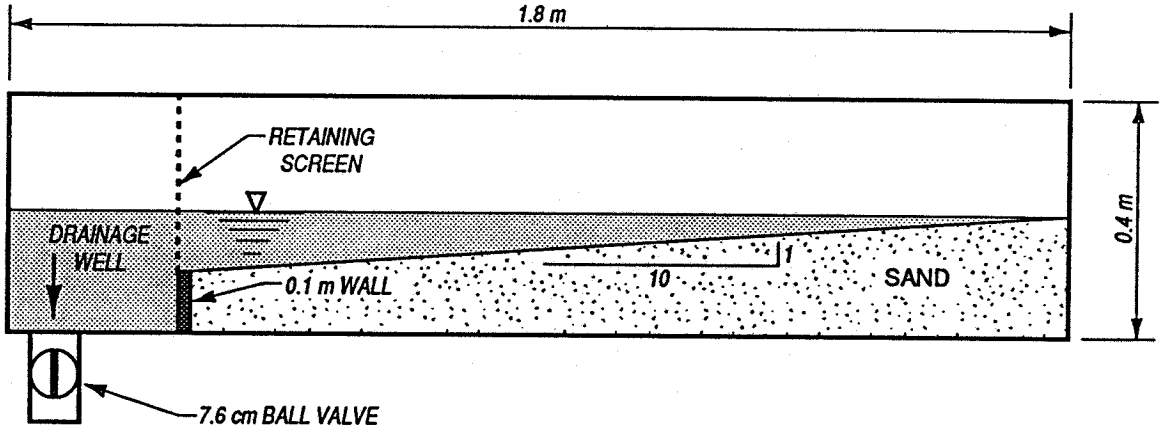
larval Sturgeon Shovelnose - part of pelagic drift
Lake - seek low velocity areas

# Stranding

Nan Bhakri
Ice Max Drawdo
0.24 m
Miss: 0.14 m

- 2 bankline configurations
- 3 levels of vertical drawdown (max 0.3 m)



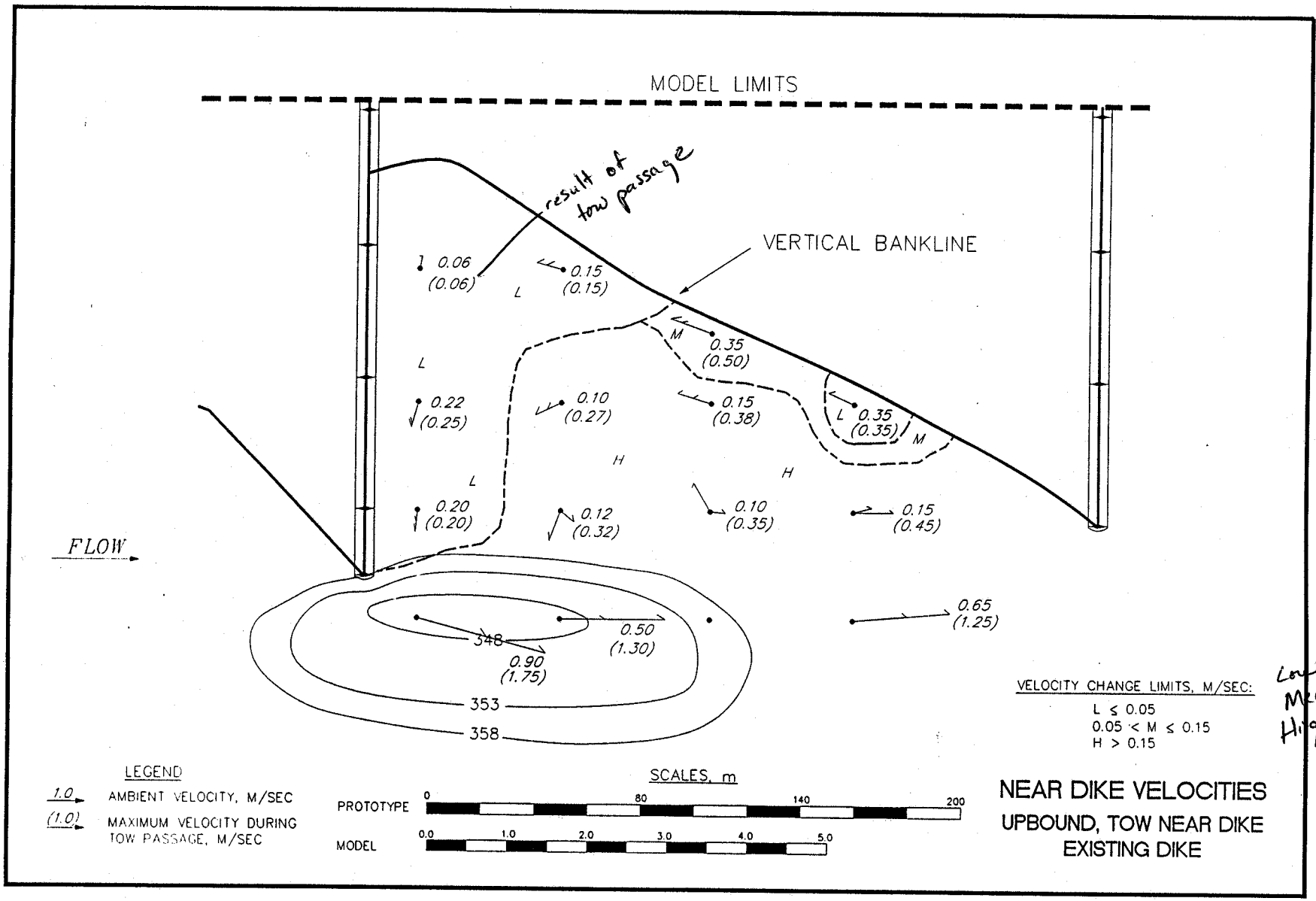




1983 leslie Holland Walleye + Pike
eight stranding events find sig. mortality

- fish orient into current
- paddlefish + sturgeon swam against the current
- ball valve removed at a specific rate
- count fish that where stranded

Table 1. Mean (± SD) percent stranded of fish species at each drawdown rate when slope was 1:5. Number of replicates (N) per drawdown rate are stated, and the sample size for each replicate was 10 fish. Shared superscripts indicate that overall means were not significantly different among species using SNK. Standard deviation (SD) for overall means are given in the text.

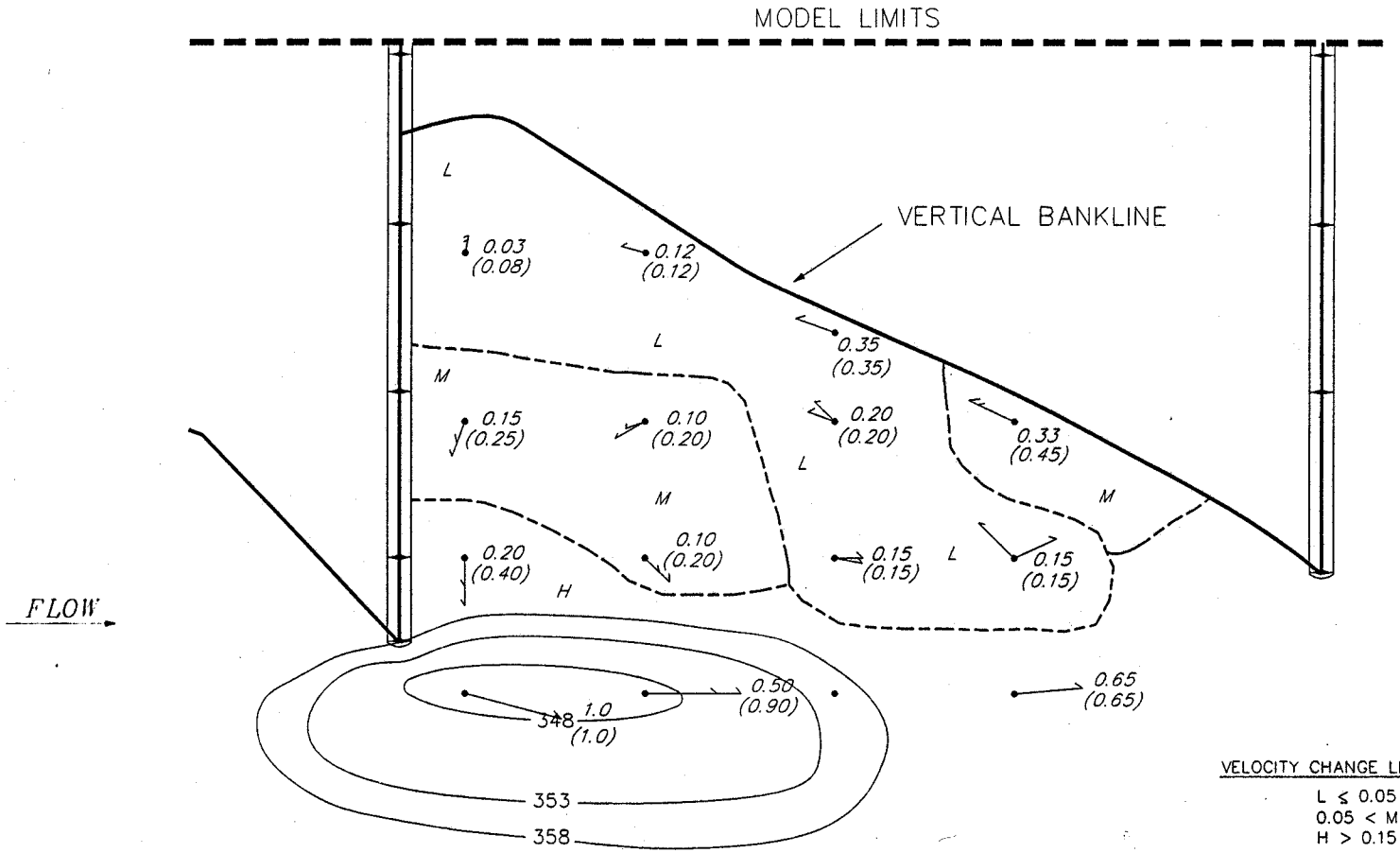
| Species | Drawdown (cm/s) | N | Percent Standed Mean | SD | Overall Mean |
|---|---|---|---|---|---|
| Shovelnose Sturgeon | 0.76 | 2 | 75.0 | 21.21 | |
| | 0.46 | 2 | 60.0 | 14.14 | |
| | 0.21 | 2 | 65.0 | 21.21 | 66.7[a] |
| Paddlefish | 0.76 | 5 | 40.0 | 10.0 | |
| | 0.46 | 5 | 32.0 | 21.68 | |
| | 0.21 | 5 | 42.0 | 10.95 | 38.0[b] |
| Bigmouth Buffalo | 0.76 | 6 | 3.3 | 5.16 | |
| | 0.46 | 6 | 3.3 | 5.16 | |
| | 0.21 | 6 | 0.0 | 0.0 | 2.2[c] |
| Largemouth Bass | 0.76 | 3 | 0.0 | 0.0 | |
| | 0.46 | 4 | 0.0 | 0.0 | |
| | 0.21 | 4 | 0.0 | 0.0 | 0.0[c] |
| Bluegill | 0.76 | 3 | 13.33 | 11.55 | |
| | 0.46 | 3 | 20.0 | 20.0 | |
| | 0.21 | 3 | 26.67 | 23.09 | 20.0[d] |




Maynard Study

Low Med High

Worst case scenario - ~~downbound~~ tow up




VELOCITY CHANGE LIMITS, M/SEC:

$L \leq 0.05$
$0.05 < M \leq 0.15$
$H > 0.15$

LEGEND

1.0 AMBIENT VELOCITY, M/SEC

(1.0) MAXIMUM VELOCITY DURING TOW PASSAGE, M/SEC

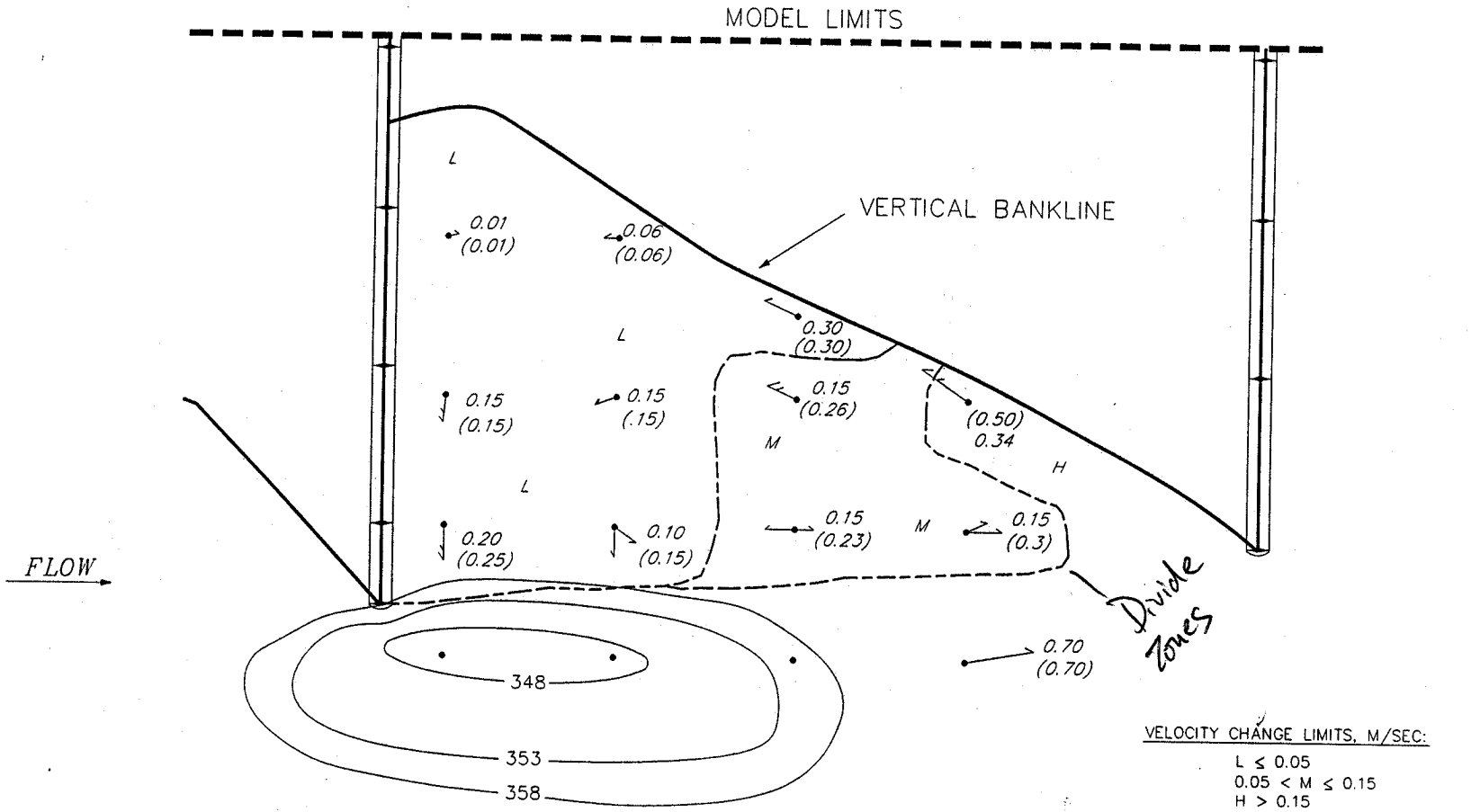
SCALES, m

PROTOTYPE 0 80 140 200

MODEL 0.0 1.0 2.0 3.0 4.0 5.0

# NEAR DIKE VELOCITIES

## DOWNBOUND, TOW NEAR DIKE EXISTING DIKE




VELOCITY CHANGE LIMITS, M/SEC:

L ≤ 0.05
0.05 < M ≤ 0.15
H > 0.15

LEGEND

1.0 AMBIENT VELOCITY, M/SEC

(1.0) MAXIMUM VELOCITY DURING TOW PASSAGE, M/SEC

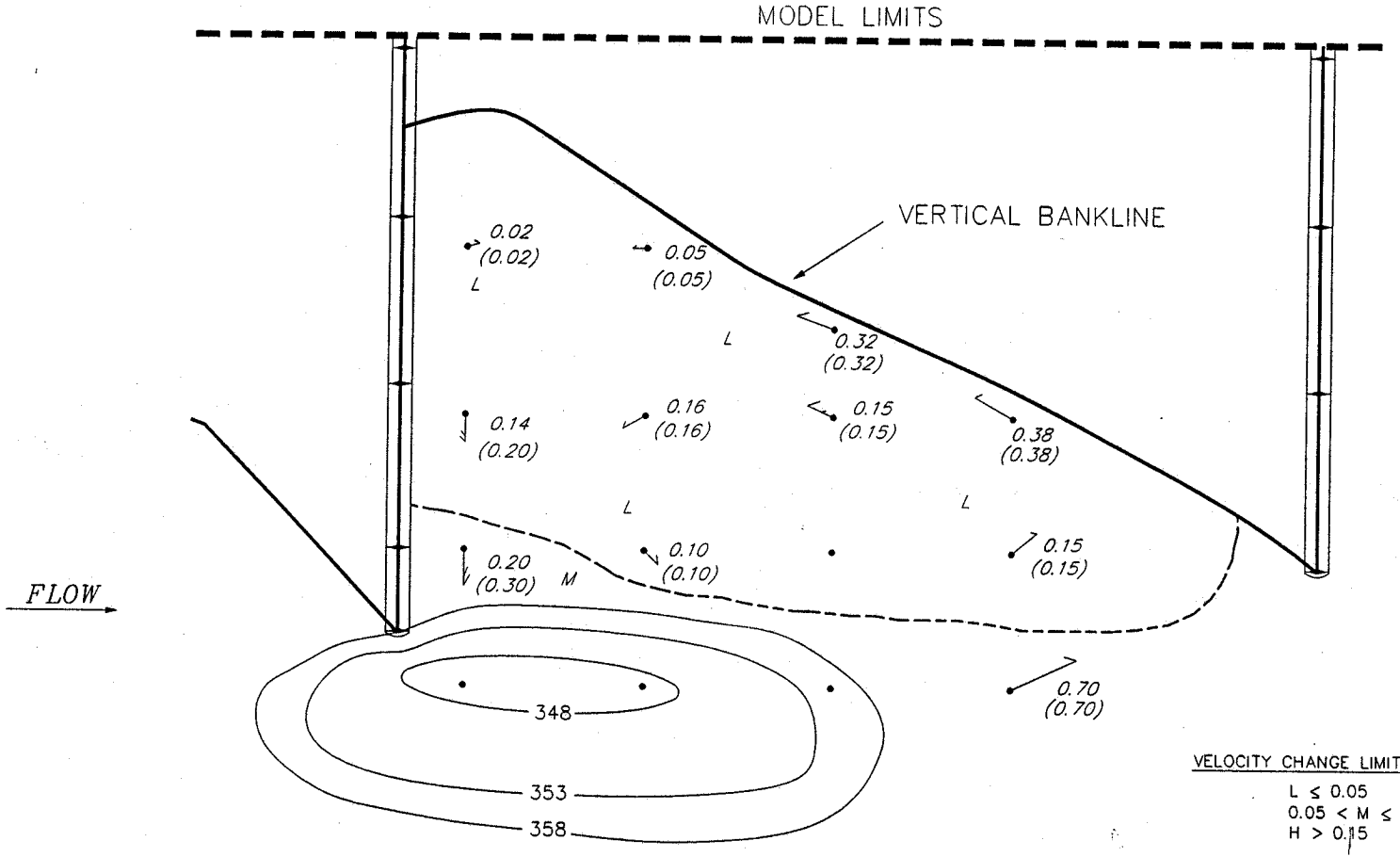
SCALES, M

PROTOTYPE 0 80 140 200

MODEL 0.0 1.0 2.0 3.0 4.0 5.0

# NEAR DIKE VELOCITIES

## UPBOUND, TOW OVER THALWEG
## EXISTING DIKE




VELOCITY CHANGE LIMITS, M/SEC:

L ≤ 0.05
0.05 < M ≤ 0.15
H > 0.15

LEGEND

1.0 → AMBIENT VELOCITY, M/SEC
(1.0) → MAXIMUM VELOCITY DURING TOW PASSAGE, M/SEC

SCALES, m

PROTOTYPE: 0, 80, 140, 200

MODEL: 0.0, 1.0, 2.0, 3.0, 4.0, 5.0

# NEAR DIKE VELOCITIES

## DOWNBOUND, TOW OVER THALWEG
## EXISTING DIKE

Table 1. Median displacement velocity (DV50) determinations at 1,2 and 4 C for channel catfish and bluegill. DV50's are the peak velocity (m/s) of a velocity change profile, similar to that of a passing barge, necessary to displace 50% of fish from their position within a test chamber. DV50s were determined using Probit analysis, p = probability of Pearson's Chi-square test of goodness-of-fit (Finney 1971). A significant p value (> 0.05) indicates the data reasonably fit the sigmoid velocity-displacement probit model.

Displacement Velocity

| Species | Temperature (C) | DV50 (m/s) | 95% Fiducial Limit | P |
|---|---|---|---|---|
| Channel Catfish 119.5 mm SL | 1 | 0.08 | 0.01-0.36 | 0.33 |
| | 2 | 0.18 | 0.11-0.23 | 0.28 |
| | 4 | 0.30 | 0.25-0.35 | 0.95 |
| Bluegill 65 mm SL | 1 | 0.09 | 0.06-0.12 | 0.38 |
| | 2 | 0.09 | 0-0.17 | 0.04 |
| | 4 | 0.16 | 0.13-0.20 | 0.11 |

Sheehan Task 8.3