ASSESSMENT OF EPA PLUME MODEL UDKHDEN PREDICTIONS IN STRATIFIED AMBIENT FLUIDS

Report Prepared for

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TABLE OF CONTENTS

INTRODUCTION

The EPA plume model UDKHDEN (Muellenhoff, 1985) has been employed by Woodward Clyde Consultants to simulate the behavior of the effluent from the outfall diffuser from the Ballast Water Treatment facility in Port Valdez, Alaska. The plume model was developed to simulate the behavior of sewage outfall diffusers which typically have much larger density differences than are associated with the treated ballast water discharges. Because of the low density differences, the effect of ambient stratification is quite pronounced and the effluent is trapped below the surface under nearly all combinations of discharge and ambient conditions. Field surveys have been conducted to measure the dilution and vertical distribution of the effluent on several occasions. Under the particular conditions of small density difference between the effluent and the ambient fluid and relatively strong ambient stratification, the effluent dilution and rise height have been measured to be larger than predicted by UDKHDEN. This behavior can be qualitatively anticipated on the basis of the model assumptions inherent in the formulation of UDKHDEN.

The purpose of this report is to compare the performance of UDKHDEN in predicting the behavior of a number of experimental data collected at the University of Michigan to examine the nature of the discrepancies with particular attention paid to the low buoyancy cases. As a result of this comparison, recommendations for the interpretation of the UDKHDEN predictions in order to achieve more accurate predictions are made. The report documents the details of the comparison and the relevant conclusions.

RECOMMENDATIONS

As a result of the comparison between the available experimental data and the UDKHDEN predictions, the following conclusions are obtained:

1. UDKHDEN generally over-predicts the dilution as a function of trajectory distance for buoyant jets in unstratified fluids. This is most likely due to the choice of entrainment coefficient in the model; no detailed investigation of the adjustment of the coefficients was performed. From previous experience with plume modelling, it is unlikely that this effect accounts for the observed discrepancies in the field surveys and the UDKHDEN predictions. This is borne out by the interpretation of the other data available as discussed in the following conclusions. The main influence of the entrainment coefficient would be on the predictions of the trapping level (these would be too low) and for cases where the stratification is so weak that the plume is not trapped below the surface. The definition of trapping level in the model is so unrelated to the location of the intrusion layer in an actual situation that any discrepancies due to the choice of the entrainment coefficient is probably irrelevant. Therefore, it is probably only for the cases of negligible stratification that the choice of entrainment coefficient is important.

2. The model use of the predicted dilution at the neutrally buoyant level (trapping level) is unjustified, particularly for discharges for low buoyancy. While it may be argued that the predictions at the trapping elevation may be more accurate predictors for certain conditions, it is observed that using the model outputs at the maximum height of rise are more consistent and provide a more meaningful means for the prediction of dilutions observed in laboratory investigations.

3. In general, the use of UDKHDEN predictions at the maximum height of rise slightly over-predicts the dilutions observed in the laboratory experiments if the discharge is vertical or if it is horizontal with strong buoyancy. It is only for the case of low buoyancy horizontal discharges that the model significantly over-predicts the dilution. This is apparently due to the inability of the model to describe the turbulence collapse due to buoyant damping, an effect which is extended over a considerable distance for a nearly nonbuoyant horizontal discharge. It is not obvious how to alter the model to correct this problem since the predictions at both the trapping level and at the maximum height of rise are qualitatively similar.

4. The features of the UDKHDEN model that consider the interaction between adjacent ports in a multiport diffuser appear to behave satisfactory as essentially analogous results are obtained for single buoyant jets and for multiport discharges.

5. The use of an alternate plume model described in Wright, et al (1982) supports the above conclusions and differs from the UDKHDEN predictions in a way that can be explained solely on the basis of adjusted entrainment coefficients. Therefore, it is unlikely that a significant improvement in the model can be obtained by adjustment of the entrainment coefficients. Rather, a different interpretation of model predictions is required along with empirical adjustments in order to reproduce the laboratory data.

The actual Ballast Water effluent diffuser differs from the laboratory experiments in that the discharge angle of the ports is at 45 ° to the horizontal and intermediate between the horizontal and vertical discharges studied in the laboratory investigations. Because of the considerable difference in model - data comparisons between the horizontal and vertical discharge, there is uncertainty as to a specific recommendation that would be appropriate for this particular application. However, with the above conclusions, it appears that UDKHDEN, when interpreted according to the recommendations outlined in this report, "fails" only when the discharge is horizontal with low buoyancy in relatively strong stratification. This is apparently due to the fact that the turbulence collapse occurs over a relatively long trajectory distance and is not properly accounted for by the entrainment relation. A strongly buoyant horizontal discharge will be diverted vertically and thus the collapse region will be similar to that for a vertical discharge. The 45° discharge should more nearly correspond to the vertical discharge condition in this regard and it is recommended that the model predictions for the ballast water diffuser be interpreted in accordance with the suggested corrections for the vertical discharges. A comprehensive laboratory study would be required to provide more specific information.

BACKGROUND

Oil contaminated ballast water from oil tankers calling on Port Valdez, Alaska is treated and then discharged into the ocean waters through a submerged outfall diffuser. Typically, this ballast water is somewhat less dense than the surrounding waters, but not so much as typical sewage effluents; the density of the discharged effluent ranges from about 12 to 24 σ_t units. Consequently, ambient stratification is nearly always important.

The EPA has a suite of plume models (Muellenhoff, 1985) for predicting dilution and spreading or trapping levels from outfall diffuser discharges. Most of these are of the integral type in which the model assumptions required in their formulation are known to fail as the jet rises above the neutrally buoyant level. In particular, they fail to account explicitly for the relatively thick intrusion layer that develops as a result of the jet collapse, (see Fig. 1 for definition of maximum height of rise, intrusion layer, etc.). A number of more or less ad-hoc assumptions are made to account for this effect and one commonly employed is to account for the "blocking" effect by assuming that the intrusion layer acts as a passive barrier to the entrainment of ambient water. This blocking effect is assumed to hold for both internal collapse and for surface spreading. Thus, if the extent of the spreading layer can be predicted by some other model, the numerical computation is terminated at the lower boundary, Koh (1983). The EPA model UDKHDEN does not explicitly account for a blocking layer, but it does terminate the computation at the neutrally buoyant level (based upon computed centerline or maximum density difference). In general, this position would be somewhat above the bottom of the intrusion layer and thus would be expected to overestimate the dilution with a blocking correction of the type proposed by Koh. However, it is possible, for example, for a vertically discharged neutrally buoyant jet to travel a considerable distance before collapsing with a considerable amount of mixing. Since UDKHDEN terminates the computation at the neutrally buoyant level, there would be no predicted dilution (i.e., a dilution of 1). An important question is thus whether or not the collapse layer prevents the entrainment of ambient fluid. The question will be of most relevance for low buoyancy discharges since the trajectory distance to the neutrally buoyant level will be a smaller fraction of the total rise height in that situation.

There is a fair amount of experimental evidence available to suggest that the existence of the intrusion layer has a far less significant influence on the dilution than suggested by the blocking correction recommended by Koh. Jirka and Harleman (1979) showed that there is a near field jump region, Fig. 2. The existence of the internal jump has been demonstrated in a number of studies. Even though they ignore entrainment within the jump, this approach predicts a reduced blocking layer thickness and thus, more dilution. Wright (1985) discussed Koh's blocking models for both unstratified and stratified cases. For the surface spreading model, he showed (also formulated by Wright and Bühler, 1986 (appended to this report)) that the inclusion of an internal jump with explicitly computed entrainment results in approximately a 35 % increase in predicted dilution when compared to Koh's model and also showed that the available experimental evidence supports this analysis. For less buoyant flows, the predicted difference can be even greater and recent evidence for single round buoyant jets indicates that the near field dilution process may be dominated by the surface jump phenomenon (unpublished data).

In the case of discharges into stratified fluids where there is an internal intrusion, Wright (1985) suggested that a conceptually similar occurrence may result. However, there is no direct observational evidence as an obvious jump region is not observed. However, in the study by Wong (1984) flow visualization indicated that a significant amount of the total entrainment inflow enters into the mixing zone from the opposite side of the intrusion layer from the jet source, indicating that the intrusion layer does not act as a passive barrier to entrainment. Those experimental studies of buoyant jets in stratified fluids, Wallace and Wright (1984) (two dimensional jets) Wright, et al, (1982) (diffusers) Wong(1984) (round buoyant jets) all arrive at the same conclusion; the integral model prediction must be continued all to the maximum height of rise in order to reasonably well predict dilution. This implies that the blocking effect is best to be totally ignored and that the assumption in UDKHDEN to terminate the computation at the neutrally buoyant level is questionable. The data mentioned above primarily consists of measurements within the intrusion layer where the near field turbulence has been completely extinguished. Therefore, all near field mixing processes are accounted for by the buoyant jet model and therefore represent the prediction desired from a model such as UDKHDEN.

MODELLING ISSUES

Because there are some differences between the UDKHDEN and the models that were used in the above referenced studies, it was decided to run the UDKHDEN model against a variety of the available experimental data, compare the dilution predictions, and arrive at a conclusion regarding the validity of the UDKHDEN predictions and possible ways to improve them.

There are a number of features of the UDKHDEN model that affect the interpretation of a comparison of predicted results against the experimental data. Those issues that are relevant to the interpretation are discussed below. A conceptually similar model formulation was described in Wright, et al (1982); this model has undergone refinements over the years but is still conceptually the same. The major differences are in the selection of entrainment coefficients, etc. This model was also run for much of the same experimental data to aid in the interpretation of the results. This is referred to below as the UM model. The differences between the two as they relate to model interpretation are discussed below. All numerical analyses were conducted on an APPLE Macintosh. Changes in the UDKHDEN program were only made to make it machine compatible and did not influence the computational logic.

FEATURES OF THE UDKHDEN AND UM MODELS

One major difference between the two models is the inclusion of the ambient current. Because of previous observations that the mechanics of the jet mixing is significantly different for a single round buoyant jet in a crossflow than for a two dimensional jet, the UM diffuser model formulation does not include the effect of a crossflow although other models have been developed to describe the extensive data set of Wright (1977) and such an effect could be included in the formulation rather easily.

One of the minor features of the UDKHDEN model that does have a somewhat important influence on the interpretation of the results is in the choice of profiles. The UDKHDEN model uses profile shapes of the sort

$$C = C_m [1 - (x/b)^{3/2}]^2$$

where C refers to the concentration, C_m is the maximum or centerline value, x is a lateral coordinate and b is a characteristic profile width. The UM model uses gaussian profiles of the sort

$$C = C_m \exp[-x/(\lambda b)]^2$$

where b is now a different characteristic width and is specifically defined as the lateral location to where the velocity drops to e $^{-1}$ of the centerline value. The multiplier λ on the concentration profile accounts for the differences in the profile widths of velocity and concentration or density. This varies between jets and plumes and also between round and two-dimensional discharges; the UM model formulation accounts for this by making it a function of the local densimetric Froude number, much as the entrainment coefficient is commonly regarded as a function of the same variable. The variation in λ has little effect on the prediction of the jet fluxes of mass, but does have an important effect on the predicted minimum dilution. For example, the average dilution S_a is defined as the ratio of the local jet volume flux q to the source value Q

$$S_a = q/Q$$

The flux weighted minimum dilution S_m is defined, however, as

$$S_m = C_0 / C_m = \frac{\int u \left(\frac{C}{C_m}\right) dA}{Q}$$

where u is the local velocity and the integral is over the jet area normal to the jet trajectory. The relationship between the S_a and S_m can be demonstrated for the UM profiles to be

Two Dimensional Buoyant Jet

$$S_a / S_m = \sqrt{\frac{1 + \lambda^2}{\lambda^2}}$$

Round Buoyant Jet

$$S_a / S_m = \frac{1 + \lambda^2}{\lambda^2}$$

and is therefore dependent both upon whether or not the diffuser discharge is computed to be merged or not and upon the specific value of λ. The relationship between the two will be different in the UDKHDEN model because of the different profile assumptions. This model does not include a λ factor in the concentration profile and thus can be integrated directly to yield for

Two Dimensional Jets

$$S_a / S_m = 1.426$$

Round Buoyant Jets

$$S_a / S_m = 1.926$$

These compare with 1.414 and 2.0, respectively for the gaussian profiles if λ is assumed to be equal to unity. Because the UDKHDEN model predicts average dilution and all of the experimental data are in terms of minimum dilution, it is important to recognize a conversion between the two and also to distinguish whether axisymmetric or two dimensional flows are being considered. For all the diffuser flows simulated, the UDKHDEN model predicts merged conditions so the two dimensional profile is valid for all of those data. In any case, if the appropriate model is to be interpreted, the model output (S_a for UDKHDEN and S_m for UM) is compared to the observed S_m. In the unstratified flow comparisons, however, the data is converted to a consistent variable; the details are discussed below.

There is a different zone of flow establishment correction in the UDKHDEN model than in the UM one. One difficulty is that it cannot simulate low Froude number discharges and these data sets are rejected in the numerical analysis. In the comparison of results below, all data sets where this is a problem are ignored.

The entrainment relations are different between the two models. I don't have complete documentation of the UDKHDEN model but it appears from the source code listing that the entrainment coefficient that is typically associated with the densimetric Froude number has been set to zero and thus that the entrainment coefficient is the same for jets and plumes. In general, previous research indictaes that the entrainment coefficient is different for a plume than for a jet and different also between round and two dimensional jets; the UM model entrainment coefficients have been optimized to describe the relevant data for unstratified jets and plumes including a feature to handle problems encountered in simulations in stratified fluids. The superiority of this entrainment formulation is easily seen in the comparison of results for the dilution versus trajectory distance in unstratified fluids as described below.

Finally, the merging or conversion from single round discharges to an equivalent line source are treated differently between the two models. The UDKHDEN model uses a superposition model that reduces the entrainment circumference as the individual jet surfaces overlap until a two dimensional condition is reached. The UM model simply converts between a round buoyant jet and a two dimensional one once the jet width reaches a certain fraction of the port spacing. In the present version of the UM model, all fluxes are kept constant in the merging computation, so the two models should be more or less equivalent except for the entrainment formulation through the merging zone. Because of the profile shapes there is a discontinuity in the minimum dilution, maximum velocity, etc. in the UM model at merging, but because of the use of the λ factor, there is no simple way to make all variables consistent even with an approach such as used in UDKHDEN model. Conceptually, the UDKHDEN model should be somewhat better in the description of the merging, but the effect is minor except right at the merging location and the differences are within the variations introduced by choice of profile shapes, entrainment coefficients, etc. as discussed above.

I have had extensive experience with the UM model in terms of the adjustment of the basic model parameters such as the entrainment coefficients, etc. Presumably, experimentation with the UDKHDEN model would result in similar experiences. An important observation has been that changes in the entrainment coefficient do not significantly alter the predicted S_m (taken at the maximum height of rise Z_m) because as the entrainment coefficient is increased, Z_m decreases, thereby decreasing the total trajectory over which the increased entrainment occurs. Therefore, it has been found that the predicted S_m is basically insensitive to variations in the entrainment coefficient whereas the maximum height of rise is much more sensitive. The dilution at the neutrally buoyant level must be more sensitive than at the maximum rise, but some of the same effect must be present since increased dilution will lower the elevation at which the neutrally buoyant level is computed to occur. Therefore, UDKHDEN will probably compute nearly the same dilutions as the UM model, but will predict somwhat lower trapping levels and maximum height of rise. These differemces between the two were observed in the intercomparison, but the effect was generally minor.

AVAILABLE DATA SETS

There were several data sets available against which the validity of the UDKHDEN model could be assessed. These include:

1.) The diffuser data reported in Wright, et al (1982). These include data from discharges from either a single side or both sides of the diffuser. The discharges were horizontal in both cases. From the original study, there appears to be little difference between the two data sets and this data can be regarded as essentially equivalent; results presented below reinforce this conclusion. The data consists of measurements of concentration profiles within the intrusion layer from which the maximum concentration was used to define S_m. These were reported in Wright, et al (1982) in terms of minimum dilution, spreading level (vertical location of the maximum concentration in the intrusion layer), and layer thickness. Also recorded were the visual observations of the maximum height of rise, Z_m. A representative profile was used to estimate the relationship between the average and minimum dilution as discussed below. There were 40 separate experiments reported in this study and a comparison with nearly all of these are reported below.

One difficulty is that the original study was intended to examine conditions that were more representative of sewage outfall discharges and so the low buoyancy cases that may be appropriate for the present problem were not examined in detail.

2. Wong (1984) made an extensive study on round buoyant jets in a stratified fluid. This included all of the types of measurements described above for the diffusers; in addition, he measured concentration profiles along the jet trajectory. For a baseline data set, he also made a few measurements in unstratified fluids and demonstrated that the results were comparable to previous data. For the stratified fluids, he studied both horizontal and vertical discharges, each for the limiting cases of essentially of pure jets and plumes. This data set has the potential for more detailed interpretation of the model predictions. When interpreted in conjunction with the diffuser data, reasonable conclusions can be developed.

In terms of the data quality, there are some minor differences between the various data. All measurements were obtained with a similar type of measurement technique. However, Wong refined the apparatus used in the original diffuser study and probably improved the quality of the measurements. Therefore, his data are probably of higher quality in general. There is no reason to expect a major problem with any of the data with one exception. The less buoyant data for the diffuser study were apparently collected without sufficient attention paid to being beyond the collapse point. Therefore they may underestimate the dilution somewhat. In the report by Wong, he reports on some of the data collected with the one-sided diffuser apparatus but with a single port discharge. In his report, much of the data is consistent with his later measurements, but some of the data indicate lower dilutions with a maximum discrepancy of approximately 50%. Therefore, this point will be kept in mind when interpreting the results.

SIMULATIONS

With the available data sets, a detailed simulation effort was conducted. This included:

A. Running the test data set supplied with the source code to verify that the model worked correctly.

B. Running five of Wong's unstratified flow data cases to compare predictions in unstratified flow to examine that effect. This included two plumelike and two jetlike cases with one intermediate case. The test cases are indicated in Table 1 which is taken from Wong's thesis.

C. Running 16 data cases from Wong's vertical jets in stratified fluids. These were taken for representative conditions that ranged from the strongly buoyant cases to jetlike flows. This was distinguished on the basis of the ratio $\mathbf{l_m/l_b}$ which is a ratio of the momentum length scale $\mathbf{l_m} = M^{3/4}/B^{1/2}$ to the maximum rise height length scale for a plume $\mathbf{l_b} = B^{1/4}/\varepsilon^{3/8}$ where $\varepsilon = - g/\rho_o \, d\rho/dz$ is the square of the buoyancy frequency. The simulations and data analysis by Wong indicate that this is a good single parameter to describe the results and representative data sets over the range of variables were considered. Table 2 which is taken from Wong's thesis identifies the basic variables.

D. Running 13 data cases from Wong's horizontal jets in stratified fluids. Again, the data sets were selected to vary over the range of variables. Table 3 identifies the relevant experiments.

E. All of the diffuser data reported in Wright, et al (1982) for which dilutions were reported. Two of the data sets had sufficiently low source Froude numbers that they were rejected by UDKHDEN, but all other data were examined. This information is summarized in the publication appended to this report.

The UM model was run on the data in set **B** and about half the data in sets **C** and **D** primarily to provide an extra basis for interpretation of results.

RESULTS

In general the results are dependent upon the ration l_m/l_b as discussed above. As discussed by Wright, et al, similar ratios may be defined for two dimensional or round buoyant jet discharges as

Two Dimensional Jets

$$l_m / l_b \text{ (2-dim)} = \frac{M/s\ \varepsilon^{1/2}}{B/s} = \frac{M\ \varepsilon^{1/2}}{B}$$

Round Jet

$$l_m / l_b \text{ (round jet)} = \frac{M^{3/4}\ \varepsilon^{3/8}}{B^{3/4}} = [l_m / l_b \text{ (2 dim.)}]^{3/4}$$

where M and B are the momentum and buoyancy fluxes per port and s is the spacing between adjacent ports. It can be seen that the ratio is independent of the port spacing and so the ratio for round buoyant jets may be considered to be descriptive of two dimensional ones as well. Furthermore, since the transitions from plumelike to jetlike flows occurs at a value of the ratio on the order of 1, the magnitude of the ratio for round jets can be taken as a rough indicator of whether the flow is jetlike or plumelike for either the diffuser or single port discharges

$l_m/l_b < 1$; Flow is buoyancy driven

$l_m/l_b > 1$; Flow is momentum driven

As discussed above, the relationship between predicted minimum and average dilution depends upon the assumed profile shapes and the particular value of the profile parameter λ. For example, the limiting value of λ in the UM model for a round plume is 1.2 and is the same for a two dimensional plume. For jets, the ratio is 1.28 for round jets and 1.4 for two dimensional ones. This results in the ratio S_a/S_m of

Round Jets -	1.61
Round Plumes -	1.69
Two Dimensional Jets -	1.23
Two Dimensional Plumes -	1.30

which are found to reproduce most available experimental data fairly well although there is considerable uncertainty for the two dimensional plume. However, the bulk of the data reported in this report are in the gravitational collapse or intrusion layer and the nature of the profiles may be considerably different. Since velocity profiles were not measured within the layer, it is not possible to directly compute the flux weighted average dilution and thus the ratio S_a/S_m as

$$S_a / S_m = \frac{C_m \int u \, dA}{\int uC \, dA}$$

However, a lower bound on the ratio S_a/S_m can be estimated by assuming that the velocity profile in the intrusion layer is uniform. Furthermore, since the turbulence is completely damped out within the intrusion layer in the laboratory experiments, the ratio taken with the standard plume profile assumptions should provide an upper bound since the concentration and velocity profiles are due in part to turbulent intermittency which vanishes in the intrusion layer. Therefore, the profile given in Wright, et al (1982) for two dimensional flow and from Wong (Fig. 3) for round jets were numerically integrated to obtain

Round Jets: $S_a/S_m = 1.625$

Two dimensional Jets: $S_a/S_m = 1.28$

Since these are almost exactly what are given above for the gaussian profiles, these will be used to convert the minimum dilutions in the experimental data to average dilution for purposes of making final recommendations.

Copies of all relevant UDKHDEN computer outputs are attached as Appendix A.

RESULTS

Dilutions along trajectory

The computations of the UDKHDEN and UM models for a jet in an unstratified fluid were made for 5 runs from the data by Wong. The results are provided in Figs. 4 and 5. Observed minimum dilutions were converted to average dilution (in Fig. 4 only) by the ratio 1.926; a ratio of 1.6 (as estimated from the gaussian profiles) would give even poorer agreement with the data. It can be seen that the predictions are quite good for the UM model, while the dilution is overestimated by the UDKHDEN simulations. The effect is more pronounced for jetlike flows than for plumes as would be expected by the use of a constant entrainment coefficient. Thus UDKHDEN appears to overestimate the dilution. This same influence is later observed in the stratified flow results as slightly higher terminal S_m dilutions but also reduced Z_m values are computed when compared to the UM model predictions.

Vertical Round Buoyant Jets in Stratified Fluids

The results of the predictions of Z_m and S_a or S_m (at Z_m) versus l_m/l_b are presented in Figs. 6 - 9. These are presented as a ratio of computed to observed parameter in each case except that the predicted S_a from UDKHDEN is compared directly to the observed S_m. The S_a computed by UDKHDEN at the neutrally buoyant level is also presented in Fig. 10, i.e. this is the given output. In addition, the trapping level prediction from each model is compared against the observed level of maximum effluent concentration within the intrusion layer in Fig. 11 and 12. There is a slight problem with the existing version of the UDKHDEN model since it doesn't printout the results exactly at Z_m; this modification would have to be made in the model to use it practically.

In general, both models somewhat underpredict the dilution (if interpreted in terms of profiles) and the maximum height of rise. If only the plume flows are considered, there is no major problem using the dilution at the trapping level, but the failure of the predicted dilution at the trapping level for the more nonbuoyant flows can be easily seen. Using the dilution predicted at the maximum rise gives nearly a constant ratio of predicted and observed dilution so the conversion between the model predictions and experimental observations is quite straightforward in either model use. Both models are nearly equivalent, although it can be seen that the higher entrainment coefficient in UDKHDEN results in slightly higher dilution and lower height of rise. The neutrally buoyant level is not a particularly good predictor of the trapping level for low buoyancy flows since the jet mixes considerably above the neutrally buoyant level, thereby raising the elevation at which the fluid would tend to level out.

Horizontal Round Buoyant Jets in Stratified Fluids

The results of the predictions of dilution at Z_m (from the UM model) and Z_t from UDKHDEN versus l_m/l_b are presented in Figs. 13-15. In all three plots, the predictions fail for nonbuoyant flows as the dilution is significantly overpredicted. The qualitative effect is the same in all three plots so the choice of the maximum height of rise for the dilution prediction is not significantly better or worse than the use of the neutrally buoyant level. The UM model is considerably better in its predictions, obviously because of its smaller entrainment coefficient, but suffers the same general effect. This must be due to the fact that the jet collapse occurs over a relatively long horizontal trajectory and either the entrainment is not well modelled or else there is more re-entrainment of jet fluid in this case.

The trapping level prediction is compared against the observed level of maximum effluent concentration within the intrusion layer in Fig. 16. The scatter at large values of l_m/l_b is due to the very small absolute values of the trapping elevation. In general, the absolute error is about the same for each case and reasonable predictions of this quantity are afforded from the model.

Diffuser Discharges into Stratified Fluids

In all cases the UDKHDEN model predicts merging before the maximum height of rise and in all but three cases before the neutrally buoyant level. The UM model predicts predicts roughly similar results; they are not presented herein. Therefore, the data can be interpreted as two dimensional flows. The results are plotted as a function of l_m/l_b (for round buoyant jets) in Figs. 17-19. The results are essentially the same as for the single round jets; in Fig. 20, the data for diffusers and single jets are presented. The squares are for the single jets, while the crosses are for the diffuser data. Although there is a minor difference between the ratio of predicted and observed dilution, much of this is apparently due to the difference in profile constants between the two cases. This conversion ratio of 1.625/1.28 (dilution ratio difference between round and two dimensional jets) would just about account for the difference between the two data sets. Thus, UDKHDEN does not seem to provide a consistent relationship between minimum and average dilution; the UM model is much more satisfactory in this regard.

In order to establish the equivalence of the discharges from one side and both sides of the diffuser, the additional plot in Fig. 21 was developed. This merely separates the two data sets with the squares indicating the discharge from a single sided diffuser. The issue of the interaction between opposing rows of ports appears to be unimportant in the interpretation of results.

In Fig. 19, the prediction of the trapping level is presented, and it is seen that the trapping level is under-predicted for nonbuoyant flows. In these data, the absolute values of the trapping elevation are larger than for the single jet discharges, therefore, the discrepancy is significant.

DISCUSSION

There are several things obvious from the comparison of the model predictions against the various experimental data. One of the most obvious of these is that the model prediction at the neutrally buoyant level has little to do with the prediction of the flow characteristics within the intrusion layer for flows that have little buoyancy. Therefore, the present implementation of the UDKHDEN model has little to offer for that situation. Even though the predictions are better for buoyancy driven flows, the dilution predictions at the maximum height of rise are superior and even these slightly under-estimate the observed dilutions. Therefore it is recommended to use the predictions at the maximum height of rise and adjust these accordingly to obtain appropriate model predictions. The present implementation of the model needs to be altered in order to provide the output for the conditions at the maximum height of rise.

A second issue is that the model apparently uses too large of entrainment coefficients. This is a relatively unimportant influence so long as the jet remains trapped below the surface, but for surfacing jets, the overestimate of the dilution may be on the order of 50 % for nonbuoyant flows. This would be for the prediction of minimum dilution with the assumed profile conversion between average and minimum dilution. The estimate of average dilution appears to be off by not more than 25% for the nonbuoyant flows. For buoyancy driven flows, the average dilution is reasonably well predicted and is at most 10% too large. Compared to the uncertainties associated with the applications in stratified fluids, these differences are relatively minor. Also, the predictions of dilution at the maximum rise in stratified fluids are less sensitive to the choice of entrainment coefficient. Therefore, the correction in entrainment coefficients may be appropriate, but not necessarily crucial.

The recommendations for the Port Valdez ballast water effluent outfall diffuser is complicated by the fact that there is a considerable difference in behavior between vertical and horizontal buoyant jets. Since the entire interactions are highly nonlinear, it is not obvious that an application for 45° port discharges may be generated by interpolating linearly between the horizontal and vertical discharge results. In general, the problem with the horizontal discharge may be complicated by both re-entrainment of jet fluid from the intrusion layer and an incorrect description of the collapse process; other data from Wong (1984) indicates that both effects may be important. Obviously, experimentation is necessary in order to resolve the question, but it is my opinion that the results for vertical diffuser would be more appropriate for the 45° port discharge since the finite angle of discharge carries the jet vertically away from the source and intrusion region, whereas the horizontal discharge creates a collapse region that completely blocks the discharge level. There are some data available for two dimensional buoyant jets in a stratified fluid to support this conclusion. Lee and Cheung (1986) present data for plane buoyant jets discharges at 45°. Their numerical model is conceptually very similar to the UM model and with very nearly the same entrainment coefficients. They indicate that their model slightly over-predicts minimum dilution by about 10% for the discharges at 45°. The same model nearly exactly predicts the vertical plane buoyant jets reported by Wallace and Wright (1984). On this basis, it is presumed that the effect of angle of discharge has an almost insignificant effect although there is a slight tendency to indicate an over-prediction of dilution with decreasing discharge angle. In the absence of other data, this is used to confirm the recommendations given herein.

In order to interpret the results in light of this recommendation, the results for vertical discharges are analyzed more completely. The ratio of S_a computed by UDKHDEN and the minimum observed dilution appears to be a decreasing function of the ratio l_m/l_b although the trend is probably not statistically significant. The average ratio S_a/S_m for all vertical discharges is 1.43 with a standard deviation of 0.18. Converting the experimental data to an average dilution by the ratio 1.625 for the thus requires an increase of 1.625/1.43 = 1.14 in the predicted dilution in order to obtain the appropriate average dilution. The results for horizontal discharges in the buoyancy driven regime are more or less equivalent. For example, the average ratio of dilutions for horizontal round buoyant jets with $l_m/l_b < 1$ is 1.37 with a standard deviation of 0.19. For the diffuser discharges, the ratio is essentially the same, except that the profile conversion factor is different. There are relatively few data in the plume region for the diffuser discharges, but the average dilution ratio is approximately 1.4 also. The conversion factor for average dilution for these cases would thus be 1.28/1.4 = 0.91. Practically, more analysis of the available data could be performed, but there is insufficient information to define average dilution in the experiments since the velocity profile was not measured. In general, a ten percent uncertainty in the estimate of average dilution for a diffuser discharge is probably acceptable anyway. Therefore, it may be satisfactory to just use the predicted average dilution at the maximum height of rise.

In general, the qualitative findings of this investigation are consistent with the field observations at the Port Valdez outfall diffuser site. When the effluent buoyancy is significant, the present implementation of the UDKHDEN model is probably satisfactory for predicting both trap depths and dilutions. However, under the low buoyancy, high stratification conditions encountered in the field study conducted in October, 1985, both the trapping level and dilution are under-predicted. The discrepancies in predicted dilution are of an appropriate magnitude for those observed in this work and it would be interesting to check the results of a revised model prediction against this data.

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TABLE 1. Identification of Test Data for Vertical Buoyant jets in Unstratified Fluids, from Wong (1984)

Experimental Conditions and Gaussian Fits to the Measurements of Tracer Concentration in the Cross-Section of a Vertical Buoyant Jet in a Uniform Stagnant Ambient Fluid

RUN	D	Q	RO	LM	EPS	X	Z	CM	SM	BT	XLM	ZLM	SQBLM	BT/LM	UDKHDEN Run #
0204-1	1.060	71.82	0.05619	16.72	0.0	0.0	35.0	0.149	6.72	3.91	0.0	2.093	0.378	0.234	
						0.0	25.0	0.207	4.83	2.70	0.0	1.495	0.271	0.161	
						0.0	20.0	0.262	3.82	2.27	0.0	1.196	0.214	0.136	
						0.0	10.0	0.509	1.97	1.33	0.0	0.598	0.110	0.079	
0208-1	1.060	65.33	0.06190	15.18	0.0	0.0	10.0	0.431	2.32	1.43	0.0	0.659	0.144	0.094	
0208-2	1.060	66.30	0.06085	15.44	0.0	0.0	35.0	0.149	6.69 (?	3.59	0.0	2.267	0.407	0.233	4
						0.0	25.0	0.208	4.81	2.81	0.0	1.619	0.293	0.182	
						0.0	20.0	0.255	3.92	2.29	0.0	1.296	0.239	0.148	
						0.0	10.0	0.515	1.94	1.38	0.0	0.648	0.118	0.089	
0208-3	1.060	82.53	0.04867	19.30	0.0	0.0	35.0	0.136	7.37	3.67	0.0	1.813	0.359	0.190	
0208-4	1.060	82 01	0.04754	19.76	0.0	0.0	35.0	0.149	6.73	3.41	0.0	1.771	0.320	0.173	
						0.0	25.0	0.225	4.45	2.66	0.0	1.265	0.212	0.135	
						0.0	20.0	0.280	3.57	2.15	0.0	1.012	0.170	0.109	
						0.0	10.0	0.527	1.90	1.31	0.0	0.506	0.090	0.066	
0210-1	0.611	66.62	0.00687	65.96	0.0	0.0	35.0	0.073	13.70	5.66	0.0	0.531	0.094	0.086	2
						0.0	25.0	0.118	8.50	3.95	0.0	0.379	0.058	0.060	
						0.0	20.0	0.144	6.95	3.52	0.0	0.303	0.048	0.053	
						0.0	10.0	0.302	3.31	1.32	0.0	0.152	0.023	0.020	
0210-2	1.060	44.53	0.06478	14.50	0.0	0.0	35.0	0.129	7.76	3.75	0.0	2.413	0.502	0.259	5
						0.0	25.0	0.189	5.29	2.90	0.0	1.724	0.343	0.200	
						0.0	20.0	0.246	4.06	2.30	0.0	1.379	0.263	0.159	
						0.0	10.0	0.474	2.11	1.42	0.0	0.690	0.137	0.098	
0211-1	1.060	30.17	0.09015	10.42	0.0	0.0	35.0	0.126	7.94	4.12	0.0	3.359	0.716	0.396	
						0.0	25.0	0.189	5.29	3.41	0.0	2.399	0.477	0.327	
						0.0	20.0	0.240	4.17	3.40	0.0	1.919	0.376	0.326	
						0.0	15.0	0.267	3.75	2.82	0.0	1.439	0.338	0.271	
						0.0	10.0	0.452	2.21	1.63	0.0	0.960	0.200	0.157	
0215-1	1.060	29.60	0.08870	10.59	0.0	0.0	35.0	0.074	13.52	4.43	0.0	3.305	1 199	0 418	3
						0.0	25.0	0.102	9.80	3.59	0.0	2.360	0.870	0.339	
						0.0	20.0	0.137	7.27	2.55	0.0	1.888	0.645	0.241	
						0.0	15.0	0.205	4.88	2.08	0.0	1.416	0.433	0.196	
						0.0	10.0	0.456	2.19	1.37	0.0	0.944	0.195	0 130	

Table 1 (Continued)

Experimental Conditions and Gaussian Fits to the Measurements of Tracer Concentration in the Cross-Section of a Vertical Buoyant Jet in a Uniform Stagnant Ambient Fluid

NOTE: * INDICATES CM > 1. WAS COMPUTED AS A GAUSSIAN FIT

RUN	D	Q	RO	LM	EPS	X	Z	CM	SM	BT	XLM	ZLM	SQBLM	BT/LM
0215-2	1.060	73.28	0.03583	26.22	0.0	0.0	35.0	0.168	5.97	3.92	0.0	1.335	0.214	0.150
						0.0	25.0	0.234	4.27	2.78	0.0	0.954	0.153	0.106
						0.0	20.0	0.284	3.52	2.44	0.0	0.763	0.126	0.093
						0.0	15.0	0.340	2.94	1.89	0.0	0.572	0.105	0.072
						0.0	10.0	0.543	1.84	1.33	0.0	0.381	0.066	0.051
0805-1	5.000	185.20	1.22430	3.62	0.0	0.0	19.3	0.600	1.67	2.81	0.0	5.319	2.040	0.776
						0.0	13.8	0.762	1.31	2.24	0.0	3.799	1.606	0.619
						0.0	8.4	0.986	1.01	2.13	0.0	2.321	1.241	0.587
						0.0	5.0	1.000*	1.00	1.88	0.0	1.381	1.224	0.520
						0.0	2.5	1.000*	1.00	2.04	0.0	0.691	1.224	0.563
0805-2	5.000	208.86	1.02084	4.34	0.0	0.0	19.3	0.616	1.62	2.62	0.0	4.435	1.658	0.603
						0.0	13.8	0.822	1.22	2.26	0.0	3.168	1.242	0.520
						0.0	8.4	1.000*	1.00	1.98	0.0	1.935	1.021	0.455
						0.0	5.0	1.000*	1.00	2.06	0.0	1.152	1.021	0.474
						0.0	2.5	1.000*	1.00	2.19	0.0	0.576	1.021	0.504
0805-3	5.000	242.65	0.86249	5.14	0.0	0.0	13.8	0.879	1.14	2.53	0.0	2.676	0.981	0.492
						0.0	10.0	0.983	1.02	2.48	0.0	1.946	0.877	0.483
						0.0	7.5	1.000*	1.00	2.52	0.0	1.460	0.863	0.490
						0.0	5.0	1.000*	1.00	2.24	0.0	0.973	0.863	0.436
						0.0	2.5	1.000*	1.00	2.26	0.0	0.487	0.863	0.440
0812-1	5.000	220.16	0.23768	18.64	0.0	0.0	39.1	0.487	2.05	5.60	0.0	2.096	0.488	0.301
						0.0	30.0	0.638	1.57	4.46	0.0	1.609	0.372	0.239
						0.0	22.5	0.711	1.41	3.97	0.0	1.207	0.334	0.213
						0.0	17.5	0.956	1.05	3.52	0.0	0.939	0.249	0.189
						0.0	13.9	0.964	1.04	3.38	0.0	0.746	0.246	0.181
0812-2	5.000	174.89	0.33382	13.27	0.0	0.0	39.1	0.492	2.03	5.99	0.0	2.944	0.679	0.451
						0.0	30.0	0.606	1.65	4.77	0.0	2.260	0.551	0.359
						0.0	22.5	0.785	27	4.02	0.0	1.695	0.426	0.302
						0.0	17.5	0.920	1.09	3.42	0.0	1.318	0.363	0.258
						0.0	13.9	0.970	1.03	3.41	0.0	1.047	0.344	0.257
0813-1	5.000	219.52	0.18961	23.37	0.0	0.0	39.1	0.558	1.79	5.52	0.0	1.672	0.340	0.236
						0.0	30.0	0.659	1.52	4.87	0.0	1.284	0.288	0.209
						0.0	22.5	0.735	1.36	4.40	0.0	0.963	0.258	0.188
						0.0	17.5	0.886	1.13	3.94	0.0	0.749	0.214	0.169
						0.0	11.0	0.962	1.04	3.26	0.0	0.471	0.197	0.139

Table 1 (Continued)

UDKHDEN Run # 1

Experimental Conditions and Gaussian Fits to the Measurements of Tracer Concentration in the Cross-Section of a Vertical Buoyant Jet in a Uniform Stagnant Ambient Fluid

RUN	D	Q	RO	LM	EPS	X	Z	SM	BT	XLM	ZLM	SQBLM	BT/L	
0818-1	1.480	100.59	0.02024	64.80	0.0	0	40.0	0.216	4.63	5.05	0.0	0.617	0.094	0.078
						0	28.8	0.273	3.66	3.71	0.0	0.444	0.074	0.057
						0	18.5	0.388	2.58	2.53	0.0	0.286	0.052	0.039
						0	11.9	0.474	2.11	1.64	0.0	0.184	0.043	0.025
						0	8.3	0.784	1.28	1.31	0.0	0.127	0.026	0.020
1005-A	0.511	80.45	0.00338	135.12	0.0	0.0	43.4	0.064	15.67	8.18	0.0	0.321	0.053	0.061
						0.0	30.0	0.096	10.41	4.74	0.0	0.222	0.035	0.035
						0.0	22.5	0.127	7.87	3.16	0.0	0.167	0.026	0.023
						0.0	15.0	0.204	4.90	2.04	0.0	0.111	0.016	0.015
						0.0	10.0	0.295	3.39	1.22	0.0	0.074	0.011	0.009
						0.0	5.0	0.456	2.19	0.63	0.0	0.037	0.007	0.005

TABLE 2. Identification of Test Data for Vertical Buoyant jets in Stratified Fluids, from Wong (1984).

Experimental Conditions and Measured Values of the Terminal Parameters for **Vertical Round Buoyancy-Dominated Jets** Discharged into Linearly Density-Stratified Stagnant Ambient Fluids

UKDHDEN RUN #	Run	Q $\left(\frac{cm^3}{s}\right)$	M $\left(\frac{cm^4}{s^2}\right)$	B $\left(\frac{cm^4}{s^3}\right)$	ϵ (s^{-2})	$\rho_a(0)$ $\left(\frac{g}{cm^3}\right)$	R_0	$\frac{\ell_M}{\ell_b'}$	z_m (cm)	z_s (cm)	S_m	h_s (cm)	z_t (cm)	z_b (cm)	R_e
7	0404-82	27.84	450.5	370.5	0.0567	1.00190	0.25819	0.395	47.00	33.50	13.40	24.00	47.00	23.00	2395.
2	0406-82	27.53	440.7	326.0	0.0250	1.00180	0.24617	0.314	68.00	49.00	25.00	-	-	-	2368.
	0518-82	21.12	259.2	415.2	0.0572	1.00150	0.41378	0.240	61.00	41.00	20.80	27.00	52.00	25.00	1817.
	0521-82	13.90	112.3	272.3	0.0295	1.00070	0.62735	0.137	65.00	45.00	27.00	28.00	61.00	33.00	1196.
	0712-82	25.79	386.7	948.3	0.0656	1.00020	0.46312	0.184	-	34.00	21.70	36.00	71.00	35.00	2219.
	0713-82	35.33	725.4	1231.6	0.0757	1.00130	0.32936	0.255	72.00	51.80	25.60	25.80	68.30	42.50	3039.
	0716-82	26.60	411.2	830.5	0.0679	0.99993	0.41393	0.215	70.00	49.00	25.60	18.00	57.00	39.00	2288.
	0727-82	36.27	764.7	1126.9	0.0905	1.00050	0.30279	0.304	61.00	38.50	18.90	31.50	51.00	19.50	3120.
4	1103-82	23.39	318.1	61.8	0.0381	1.00280	0.13685	1.004	39.00	25.75	6.90	10.00	33.00	23.00	2012.
6	1105-82	16.14	151.5	74.3	0.0334	1.00190	0.26176	0.477	46.00	31.00	9.10	11.00	39.00	28.00	1389.
	1110-82	20.92	254.3	186.2	0.0360	1.00260	0.28104	0.363	55.00	38.00	14.30	14.50	46.50	32.00	1800.
5	1111-82	41.89	1020.1	327.8	0.0415	1.00270	0.13154	0.711	62.50	40.10	10.30	17.50	50.50	33.00	3604.
1	1112-82	30.67	546.7	254.9	0.0417	1.00280	0.18524	0.538	56.50	35.20	11.20	13.25	45.75	32.50	2639.
	0111-83	16.77	163.4	296.8	0.1210	1.00270	0.49454	0.289	43.50	28.75	13.90	10.00	36.50	26.50	1443.

Table 2 (Continued).

Experimental Conditions and Measured Values of the Terminal Parameters for **Vertical Round Momentum-Dominated Jets** Discharged into Linearly Density-Stratified Stagnant Ambient Fluids

Run	Q $\left(\frac{cm^3}{s}\right)$	M $\left(\frac{cm^4}{s^2}\right)$	B $\left(\frac{cm^4}{s^3}\right)$	ϵ (s^{-2})	$\rho_a(0)$ $\left(\frac{g}{cm^3}\right)$	R_0	$\frac{\ell_M}{\ell_b'}$	z_m (cm)	z_s (cm)	S_m	h_s (cm)	z_t (cm)	z_b (cm)	R_e
0219-82	29.32	973.9	327.2	0.0290	1.00190	0.09748	0.601	63.80						3522.
0303-82A	58.50	3877.5	618.3	0.0505	1.00220	0.04754	1.294	63.50			13.50¬			7027.
0303-82B	57.03	3685.6	608.5	0.0580	1.00220	0.04899	1.327	63.50	35.00		14.00¬			6850.
0303-82C	32.07	1165.2	351.8	0.0446	1.00140	0.08836	0.765	57.00	28.00		24.00¬			3852.
0527-82	25.63	3203.0	492.2	0.0502	1.00080	0.02360	1.327	72.00	46.50	33.60	34.00	61.50	27.50	6386.
1014-82	21.12	2174.6	113.8	0.0643	1.00070	0.01517	3.265	52.00	30.25	23.80	16.00	40.00	24.00	5262.
1020-82	48.10	2621.2	216.7	0.0392	1.00110	0.03775	1.925	67.00	38.00	15.20	21.00	53.00	32.00	5778.
1028-82	39.50	1768.4	216.5	~0.0908	1.00190	0.05068	1.965	46.50	26.50	10.20			20.50	4745.
1102-82	25.96	763.4	111.8	0.0522	1.00180	0.06840	1.396	43.00	25.50	10.20	10.25	32.75	22.50	3118
0929-82	49.48	11939.0 -	189.0	0.1014	1.00110	0.00545	9.497	66.00	37.50	26.30	26.75	51.25	24.50	12329.
1001-82	58.50	16684.6	303.9	0.0667	1.00020	0.00538	7.306		48.75	34.50	34.00	63.50	29.50	14576.

• Round experimental tank - Sampling by 26-probe rake
Round experimental tank - Sampling by 13-probe rake
+ Non-linear density stratification
¬ Visual reading of spreading layer thickness

UDKHDEN RUN # 8 14 9 10 11 12

Table 2 (Continued).

Experimental Conditions and Measured Values of the Terminal Parameters for Vertical Round Momentum-Dominated Jets Discharged into Linearly Density-Stratified Stagnant Ambient Fluids

Run	Q $\left(\frac{cm^3}{s}\right)$	M $\left(\frac{cm^4}{s^2}\right)$	B $\left(\frac{cm^4}{s^3}\right)$	ϵ $\left(s^{-2}\right)$	$\rho_a(0)$ $\left(\frac{g}{cm^3}\right)$	R_0	$\frac{\ell_M}{\ell_b'}$	z_m (cm)	z_s (cm)	S_m	h_s (cm)	z_t (cm)	z_b (cm)	R_e
1006-82	31.13	4725.7	112.8	0.0762	1.00140	0.00844	6.272	56.00	32.00	25.50	20.50	43.50	23.00	7757.
1019-82	63.36	19574.6	341.4	0.1494	1.00100	0.00506	10.215	67.00	37.50	28.60	28.00	52.00	24.00	15787.
0406-83*	21.22	2195.0	395.1	0.3190	1.00590	0.02807	2.358	33.20	19.25	16.70	15.00	29.50	14.50	5287.
0406-83#	21.22	2195.0	395.1	0.3190	1.00590	0.02807	2.358	–	20.00	15.70	12.00	26.50	14.50	5287.
0407-83*	7.38	1420.0	11.5	0.1440	1.00440	0.00287	17.874	31.20	17.50	34.80	11.50	24.50	13.00	4252.
0407-83#	7.38	1420.0	11.5	0.1440	1.00440	0.00287	17.874	–	16.50	32.40	11.00	24.00	13.00	4252.
0408-83*	17.28	1455.0	25.1	0.1730	1.00440	0.00963	10.887	31.20	16.50	14.70	10.00	22.50	12.50	4306.
0408-83#	17.28	1455.0	25.1	0.1730	1.00440	0.00963	10.887	–	16.50	14.40	10.00	22.50	12.50	4306.
0124-84	14.78	5766.0	36.6	0.1370	1.00130	0.00178	21.106	55.50	16.00	75.80	28.00	44.50	16.50	8515.
0202-84+	19.27	9676.0	52.4	0.1420	1.00180	0.00145	24.075	62.50	33.50	46.10	30.50	51.00	20.50	11102.
0203-84	6.74	1183.0	5.4	0.0478	1.00280	0.00225	18.257	45.50	25.50	47.60	17.00	36.00	19.00	3883.

* Round experimental tank - Sampling by 26-probe rake
\# Round experimental tank - Sampling by 13-probe rake
\+ Non-linear density stratification
¬ Visual reading of spreading layer thickness

TABLE 3. Identification of Test Data for Horizontal Buoyant jets in Stratified Fluids, from Wong (1984)

Experimental Conditions and Measured Values of the Terminal Parameters for **Horizontal Buoyancy-Dominated Jets** Discharged into Linearly Density-Stratified Stagnant Ambient Fluids

Run	Q $\left(\frac{cm^3}{s}\right)$	M $\left(\frac{cm^4}{s^2}\right)$	B $\left(\frac{cm^4}{s^3}\right)$	ϵ (s^{-2})	$\rho_a(0)$ $\left(\frac{g}{cm^3}\right)$	R_0	$\frac{\ell_M}{\ell_b'}$	z_m (cm)	z_s (cm)	S_m	h_s (cm)	z_t (cm)	z_b (cm)	R_e
0519-83	27.69	445.6	213.9	0.0861	1.00410	0.19781	0.691	35.00	17.00	10.80	21.00	32.50	11.50	2382.
0830-83	16.91	166.2	285.3	0.1050	1.00320	0.47864	0.286	42.00	26.50	16.40	15.00	37.00	22.00	1455.
0901-83	13.68	108.9	247.7	0.0754	1.00170	0.61202	0.205	45.00	29.50	20.20	14.00	37.50	23.50	1177
0913-83	10.93	69.5	209.8	0.0954	1.00170	0.78894	0.181	39.00	26.50	19.10	16.00	37.50	21.50	940.
0916-83	27.23	839.9	371.2	0.0658	1.00160	0.11603	0.665	39.00	18.00	19.80	19.30	34.05	14.75	3271.
0919-83	38.64	1692.0	457.5	0.0965	1.00970	0.07616	1.110	24.50	10.00	15.00	21.50	25.00	3.50	4641.
0920-83	19.99	452.8	261.3	0.0860	1.00090	0.15470	0.602	35.00	24.00	19.20	18.50	33.50	15.00	2401.
0929-83	19.67	224.9	506.1	0.0203	1.00050	0.50808	0.126	-	-	-	-	-	-	1692.
0930-83	16.51	158.5	344.4	0.0683	1.00440	0.54481	0.204	50.50	23.50	24.40	16.30	45.80	29.50	1420.
1003-83	34.05	1314.0	860.1	0.0686	1.00100	0.12623	0.503	65.00	34.00	31.10	25.50	50.50	25.00	4090.
1004-83	14.47	121.7	352.7	0.0989	1.00130	0.67229	0.189	51.00	32.00	23.70	17.50	43.50	26.00	1245.
1011-83B	11.51	150.2	191.4	0.0991	1.00220	0.30284	0.350	38.50	25.00	20.70	15.50	34.50	19.00	1383.
1012-83	17.32	174.4	1104.0	0.0822	1.00210	0.90803	0.098	65.00	46.50	61.70	14.50	57.00	42.50	1490.
1014-83	20.12	235.5	1242.0	0.1370	1.00420	0.76860	0.136	54.00	37.50	25.00	19.50	47.50	28.00	1731.
1017-83	19.10	212.0	1260.0	0.0532	1.00070	0.83811	0.087	-	-	-	-	-	-	1643.
1019-83	18.58	200.6	1233.0	0.0287	1.00050	0.86420	0.068	65.00	-	81.00	-	-	-	1598.
0127-84	31.27	568.3	587.3	0.0889	1.00320	0.27311	0.394	51.50	-	-	-	-	-	2690.

UDKHDEN Run # 1 2 5 3 4 6

Table 3 (Continued).

Experimental Conditions and Measured Values of the Terminal Parameters for Horizontal Momentum-Dominated Jets Discharged into Linearly Density-Stratified Stagnant Ambient Fluids

UDKHDEN Run #	Run	Q $\left(\frac{cm^3}{s}\right)$	M $\left(\frac{cm^4}{s^2}\right)$	B $\left(\frac{cm^4}{s^3}\right)$	ε (s^{-2})	$\rho_a(0)$ $\left(\frac{g}{cm^3}\right)$	R_0	$\frac{\ell_M}{\ell_b'}$	z_m (cm)	z_s (cm)	S_m	h_s (cm)	z_t (cm)	z_b (cm)	R_e
13	0505-83	19.88	1928.0	10.9	0.0297	1.00280	0.00514	12.955	-	2.50	19.80	24.00	16.00	-8.00	4953.
8	0509-83	7.38	265.7	5.8	0.0356	1.00240	0.01654	5.054	-	5.00	22.50	15.00	11.00	-4.00	1839.
14	0510-83	29.20	4149.0	20.0	0.0394	1.00150	0.00392	16.261	-	1.00	22.20	29.50	15.50	-14.00	7276.
9	0511-83	12.01	703.5	9.5	0.0274	1.00130	0.01020	6.572	-	1.50	22.90	20.00	11 50	-8.50	2992.
	0512-83	38.42	7197.0	168.7	0.0765	1.00480	0.00753	6.366	-	1.10	35.80	30.50	19.50	-11.00	9573.
15	0513-83	11.34	3354.0	23.3	0.0489	1.00250	0.00214	13.401	-	1.00	55.00	28.00	16.00	-12.00	6533.
7	0922-83	22.16	2395.0	117.6	0.0380	1.00030	0.01434	2.813	17.00	10.00	23.30	27.00	22.00	-5.00	5522.
	0923-83	12.70	786.1	59.6	0.0275	0.99988	0.02355	1.799	22.00	10.00	29.20	24.50	25.00	0.50	3164.
	0926-83	27.23	3614.0	160.1	0.0220	0.99957	0.01230	2.475	25.00	22.50	32.30	40.00	32.50	-7.50	6785.
12	0927-83+	12.20	3880.0	67.4	0.0491	0.99954	0.00327	6.750	26.00	9.50	61.30	39.00	26.00	-13.00	7029.
13	1005-83	25.79	17335.0	487.6	0.0305	1.00020	0.00286	3.933	31.00	12.00	74.60	51.50	37.50	-14.00	14858.
	1006-83	21.72	12296.0	364.9	0.0670	1.00180	0.00320	5.075	25.00	5.00	64.00	38.50	23.50	-15.00	12513.
10	1010-83	25.79	17335.0	469.6	0.0774	1.00120	0.00281	5.737	20.00	7.50	57.10	-	-	-	14858.
	1011-83A	18.98	1756.0	332.8	0.0811	1.00120	0.03046	1.357	27.00	13.00	27.40	27.00	29.00	2.00	4729.

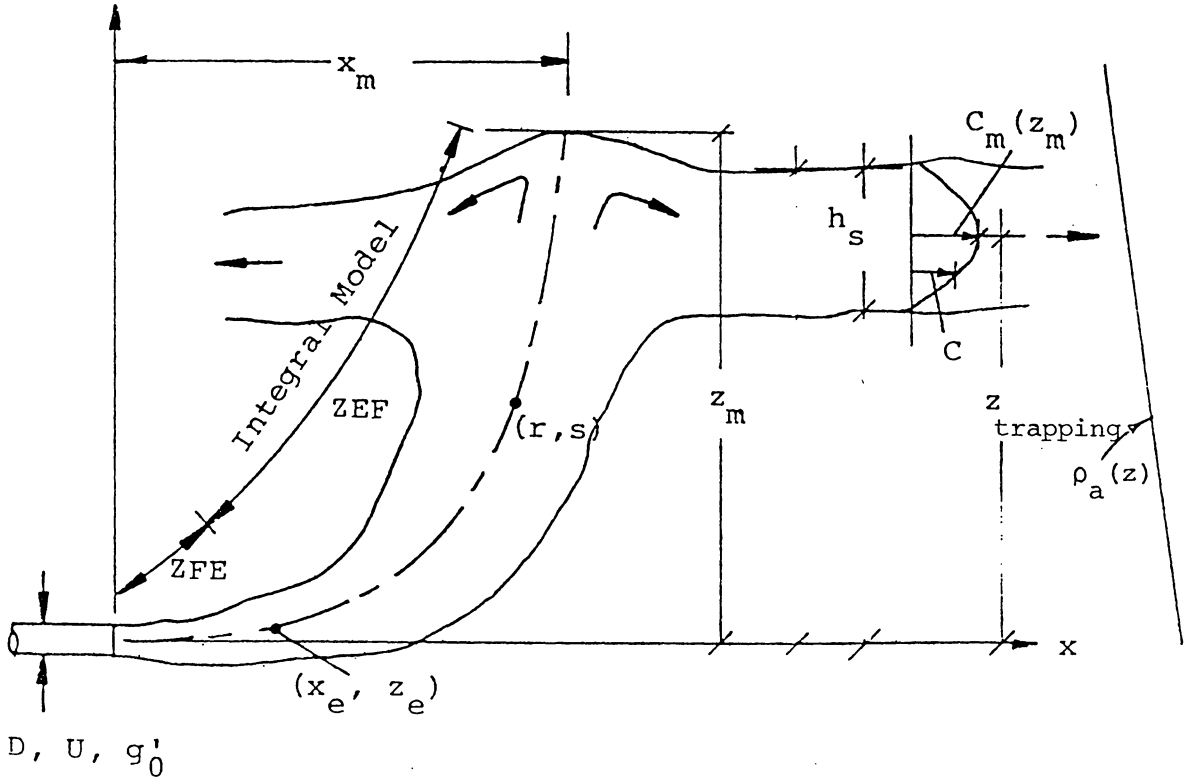

Figure 1. Internal Intrusion of a Buoyant Jet in a Stratified Fluid.

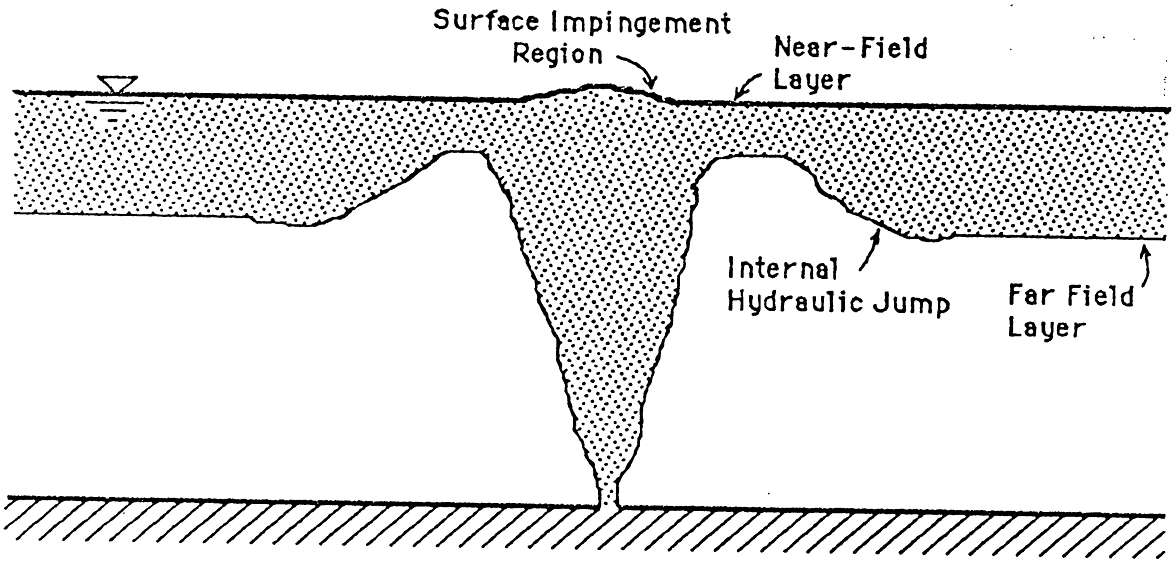

Figure 2. Surfacing Buoyant Jet with Internal Jump.

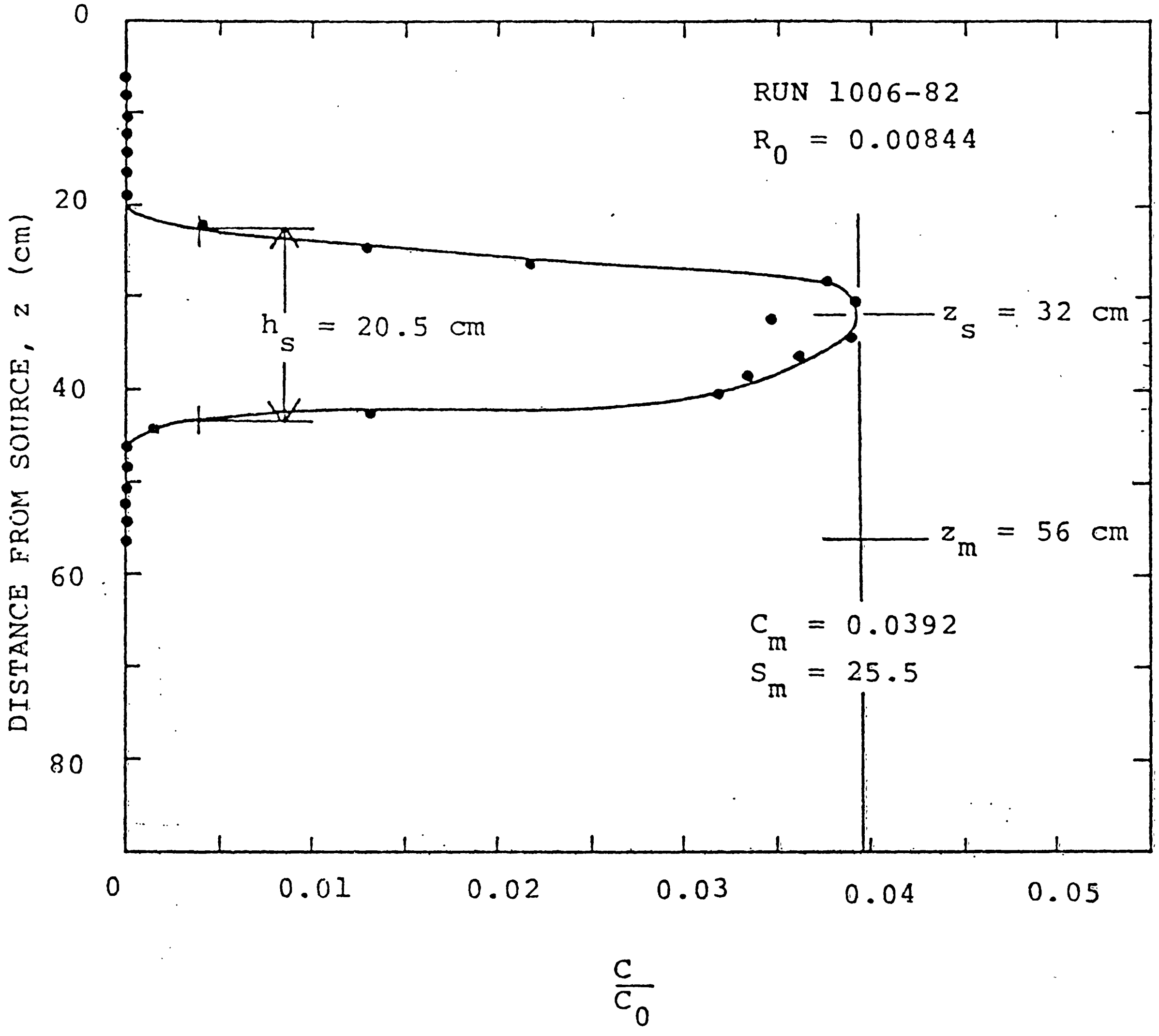

Figure 3. Typical Concentration Profile in Intrusion Layer, from Wong (1984).

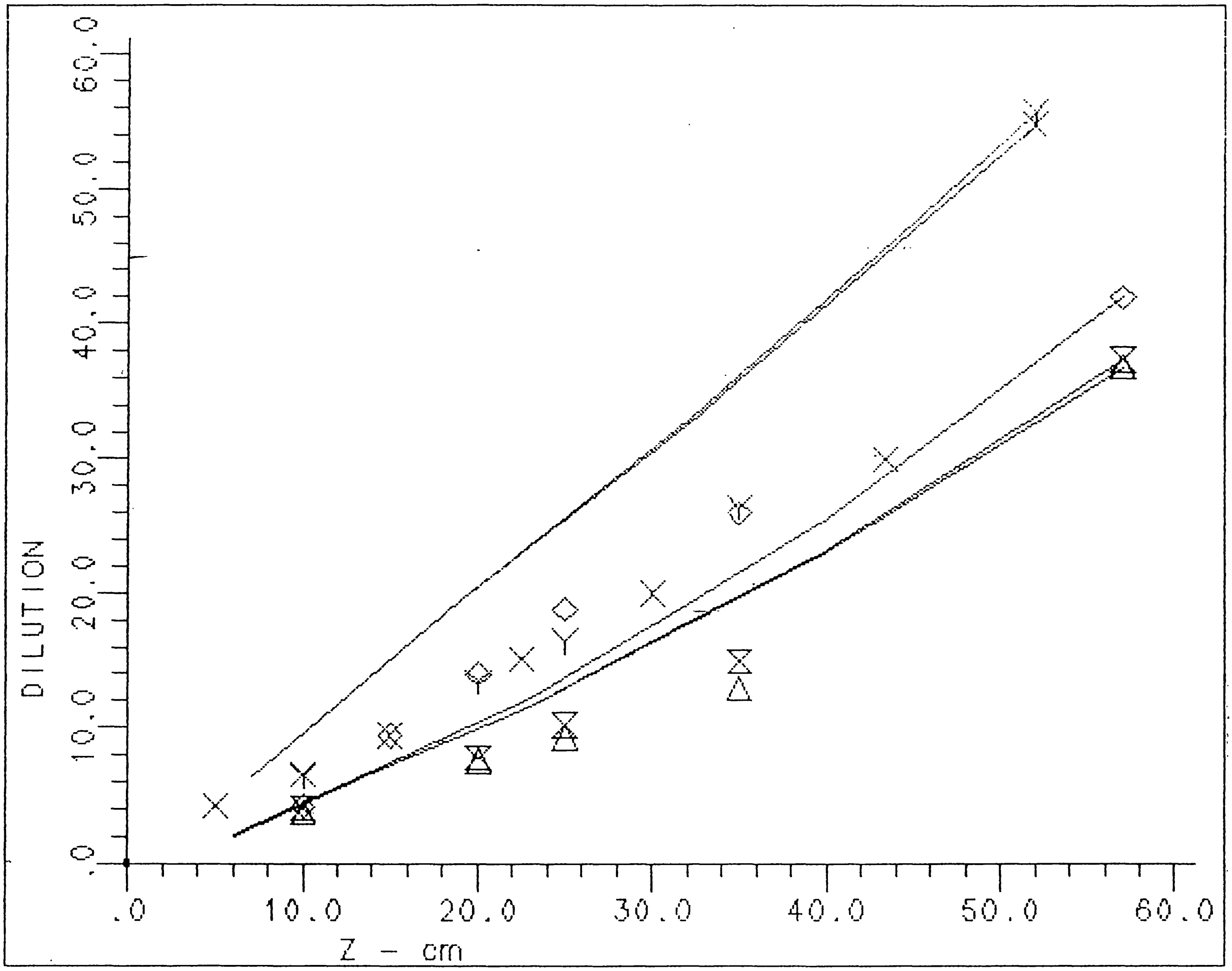

Figure 4. UDKHDEN Predictions of Average Dilution versus Trajectory Distance for Buoyant Jets in Unstratified Ambient Fluid.

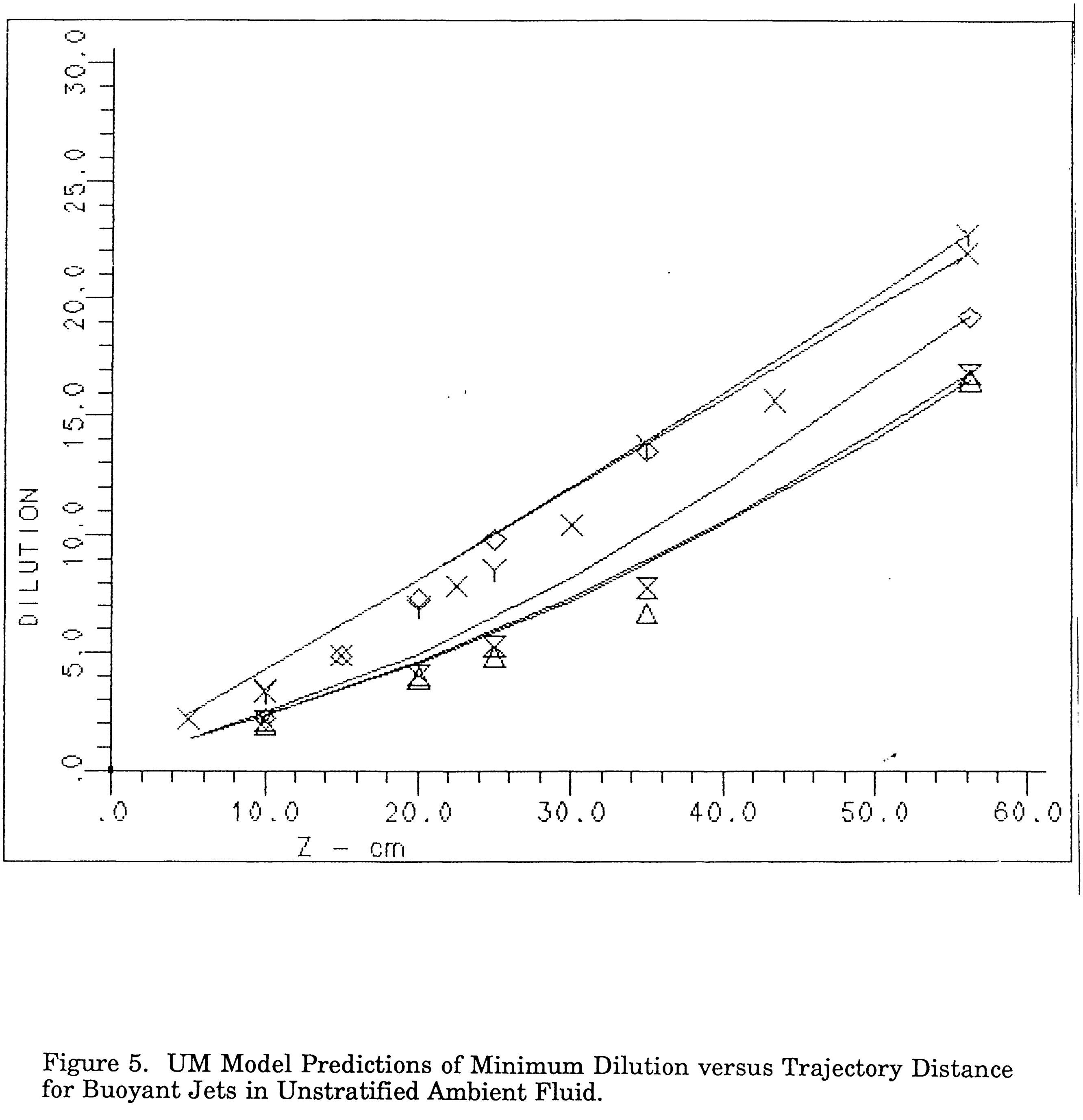

Figure 5. UM Model Predictions of Minimum Dilution versus Trajectory Distance for Buoyant Jets in Unstratified Ambient Fluid.

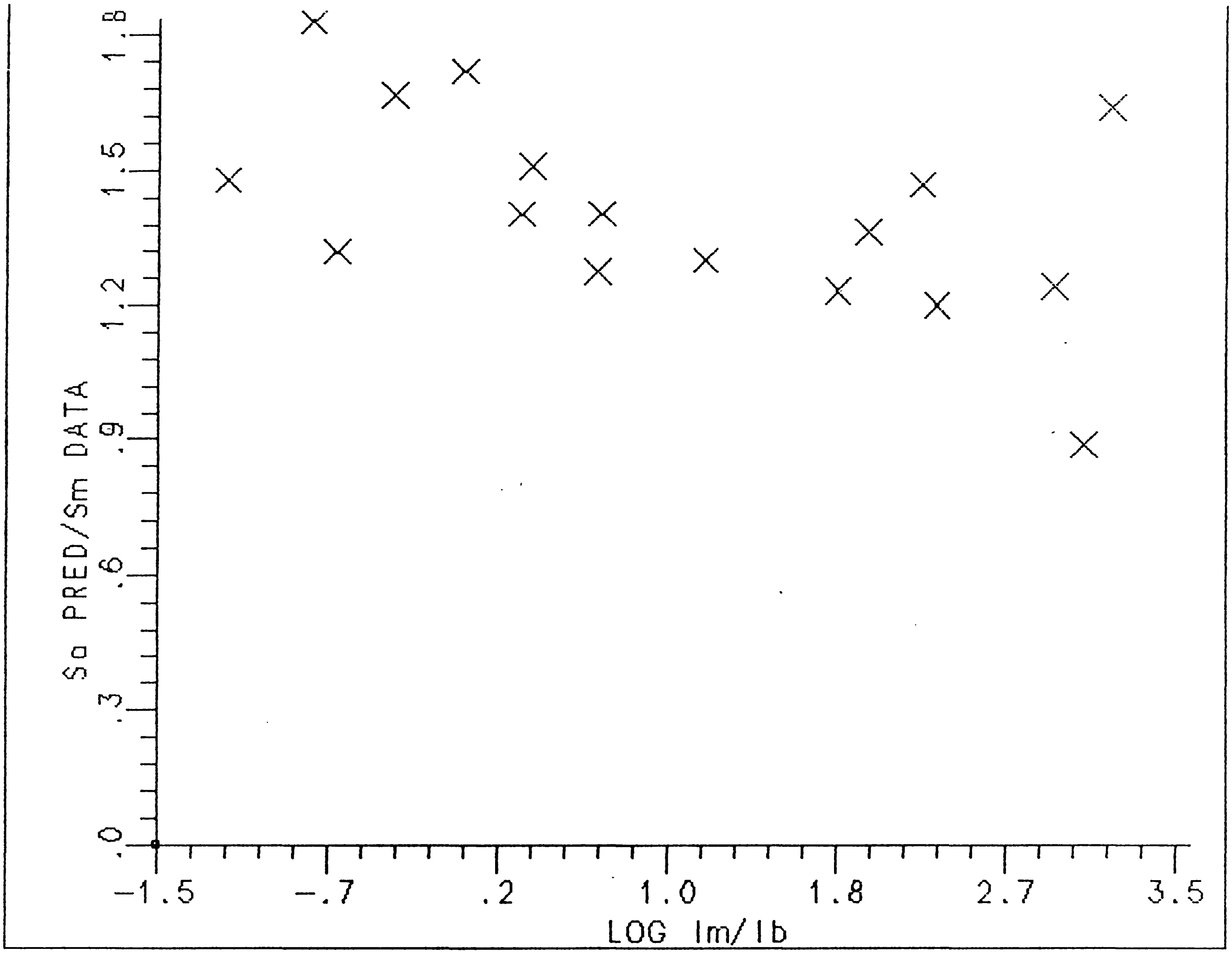

Figure 6. UDKHDEN Predictions of Dilution at Maximum Height of Rise for Vertical Buoyant Jets in Stratified Ambient Fluid.

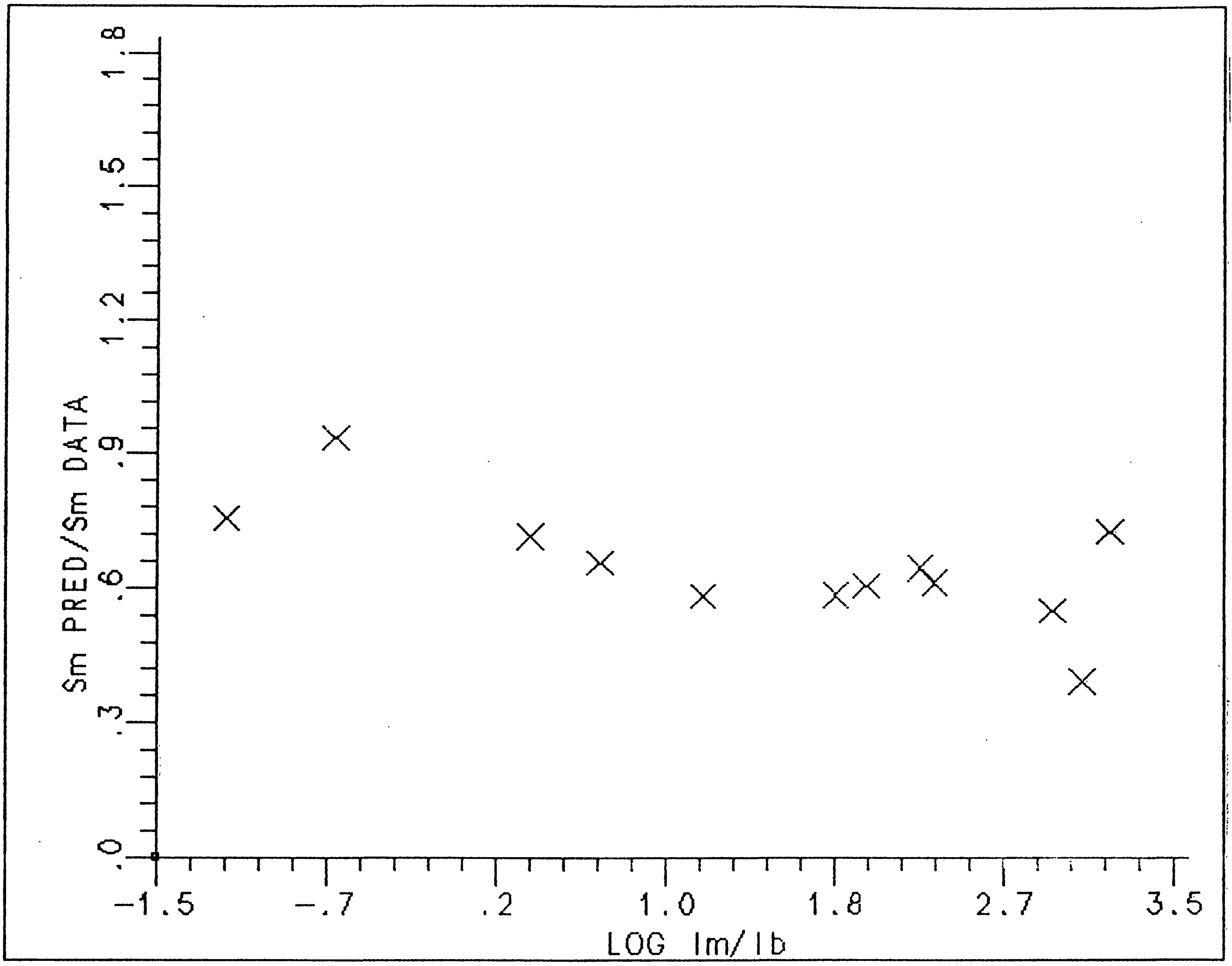

Figure 7. UM Model Predictions of Dilution at Maximum Height of Rise for Vertical Buoyant Jets in Stratified Ambient Fluid.

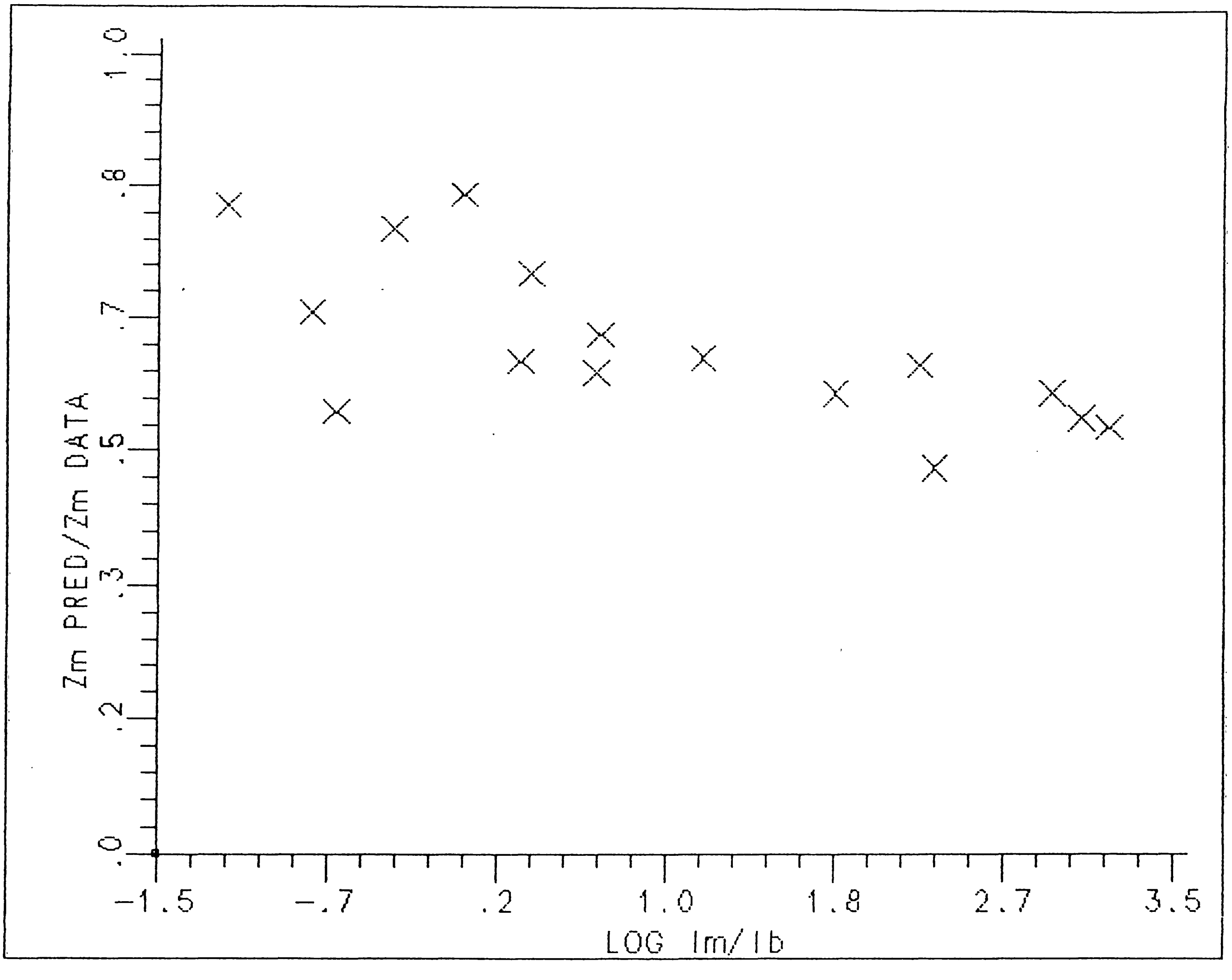

Figure 8. UDKHDEN Predictions of Maximum Height of Rise for Vertical Buoyant Jets in Stratified Ambient Fluid.

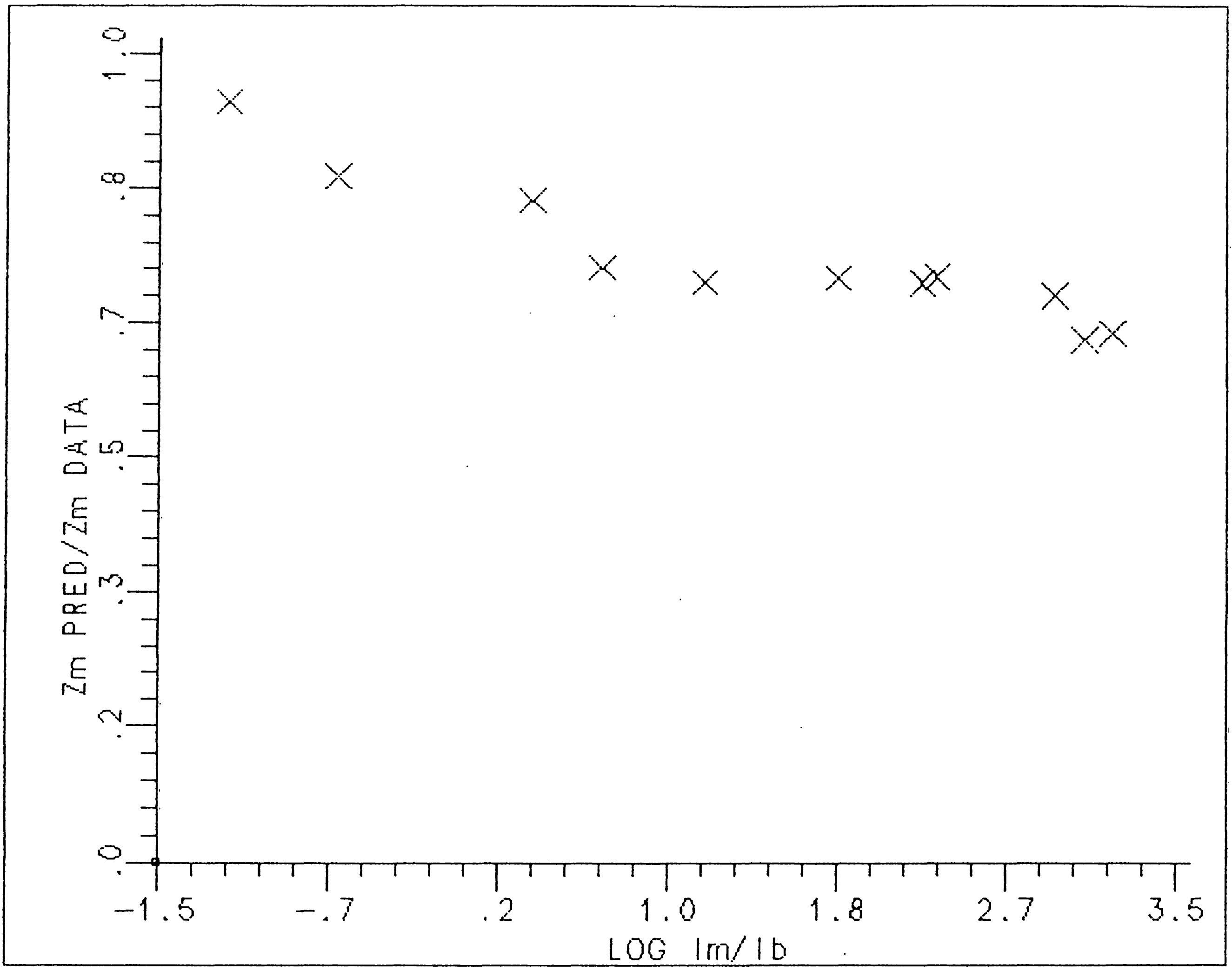

Figure 9. UM Model Predictions of Maximum Height of Rise for Vertical Buoyant Jets in Stratified Ambient Fluid.

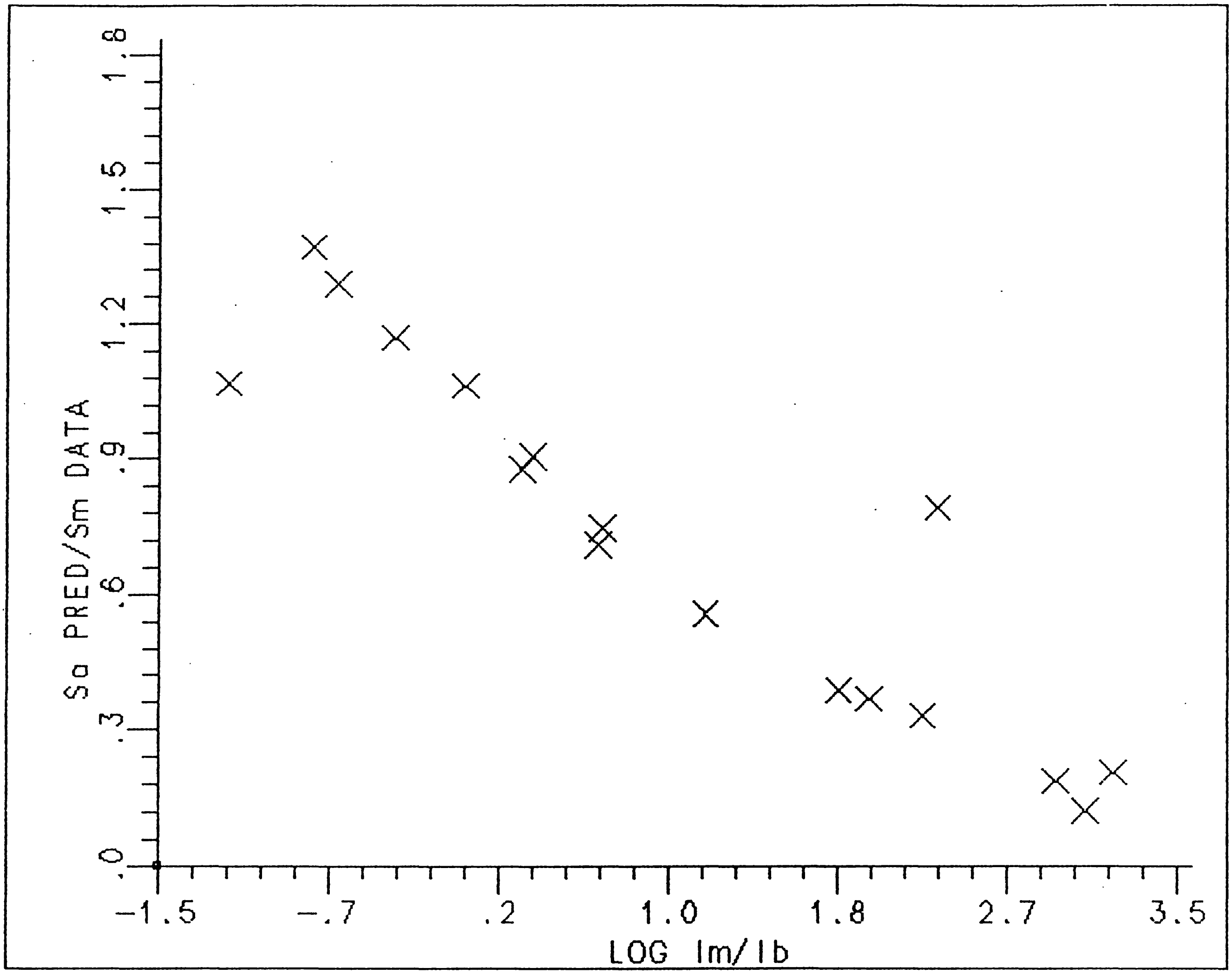

Figure 10. UDKHDEN Predictions of Dilution at Trapping Level for Vertical Buoyant Jets in Stratified Ambient Fluid.

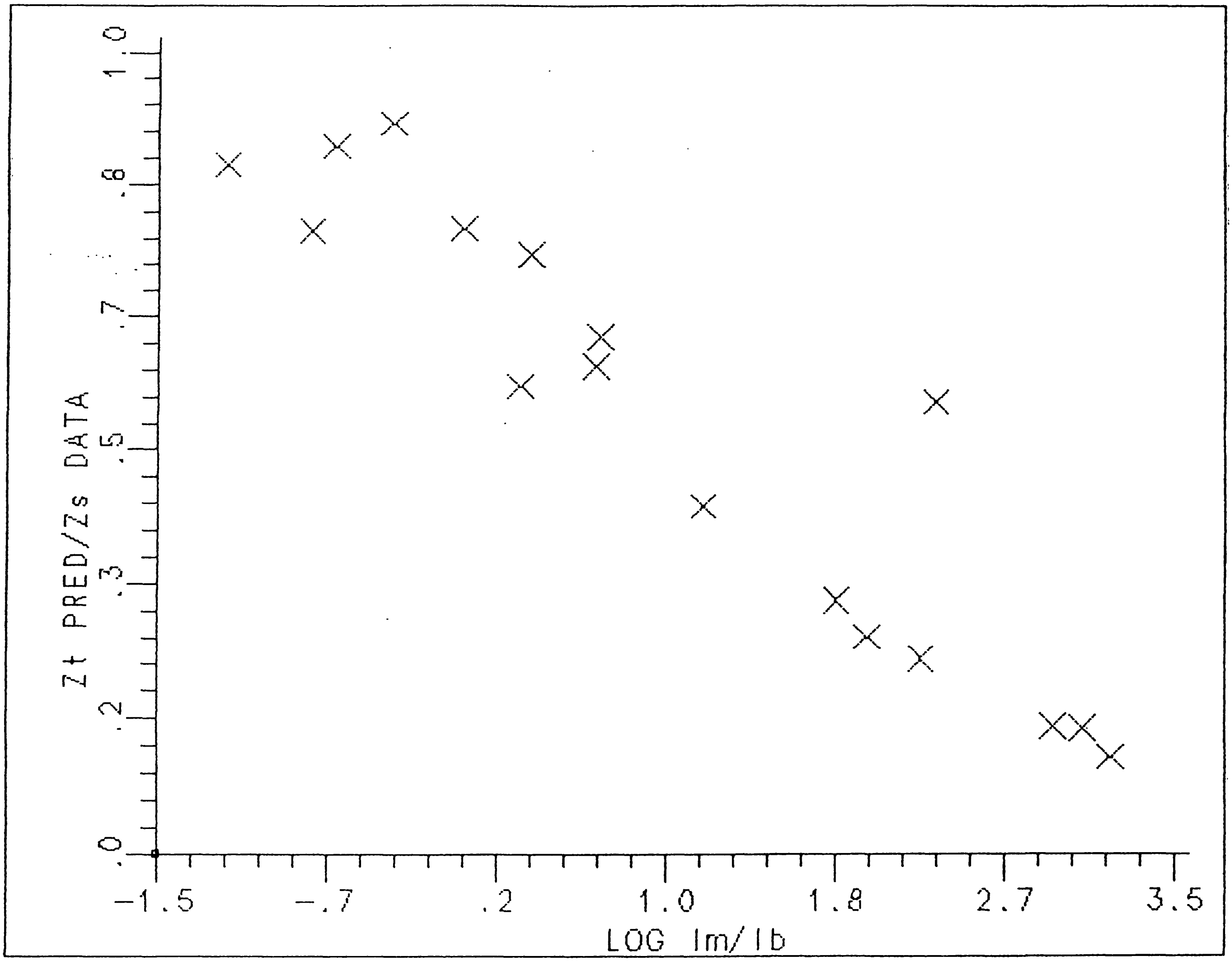

Figure 11. UDKHDEN Predictions of Trapping Level for Vertical Buoyant Jets in Stratified Ambient Fluid.

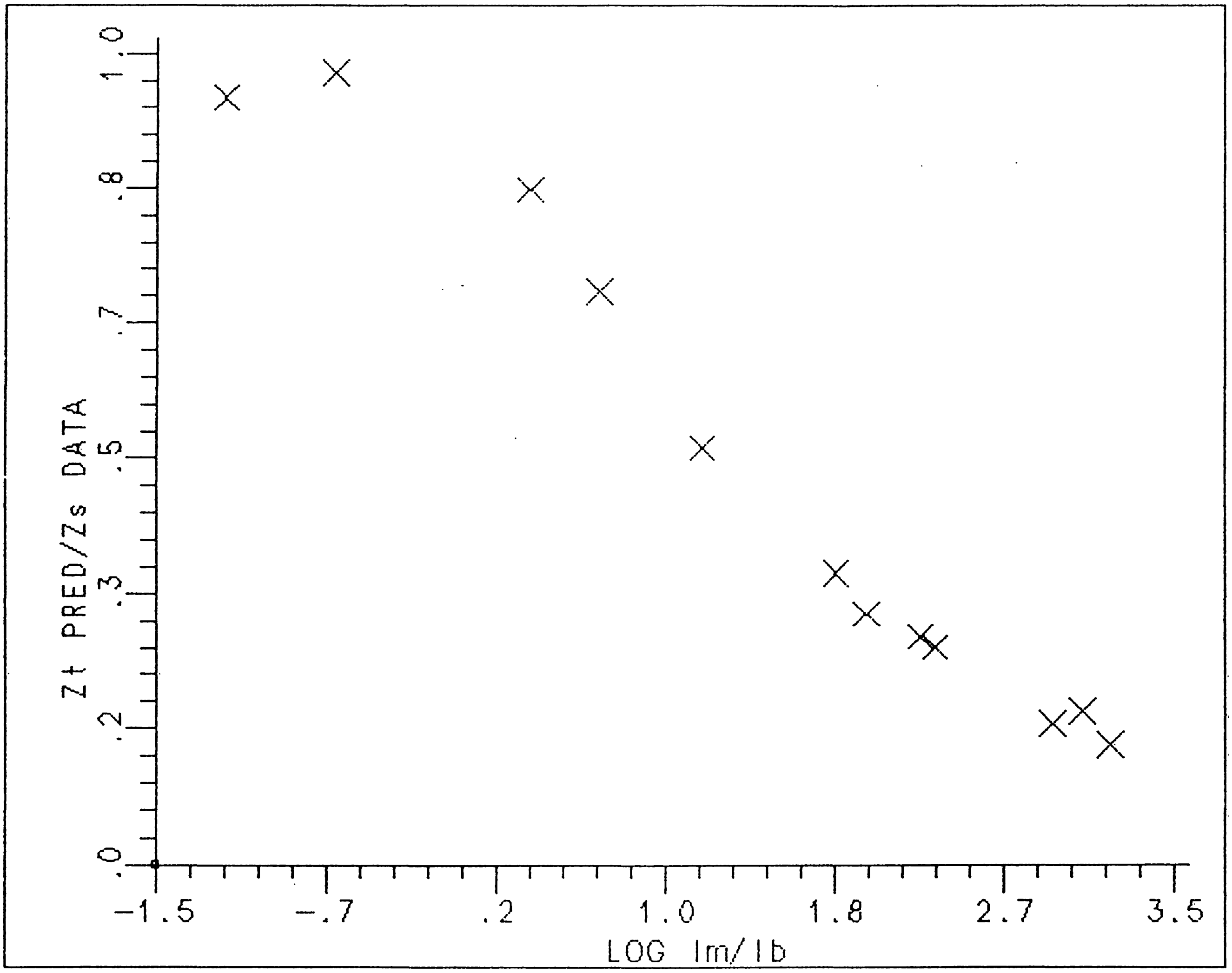

Figure 12. UM Model Predictions of Trapping Level for Vertical Buoyant Jets in Stratified Ambient Fluid.

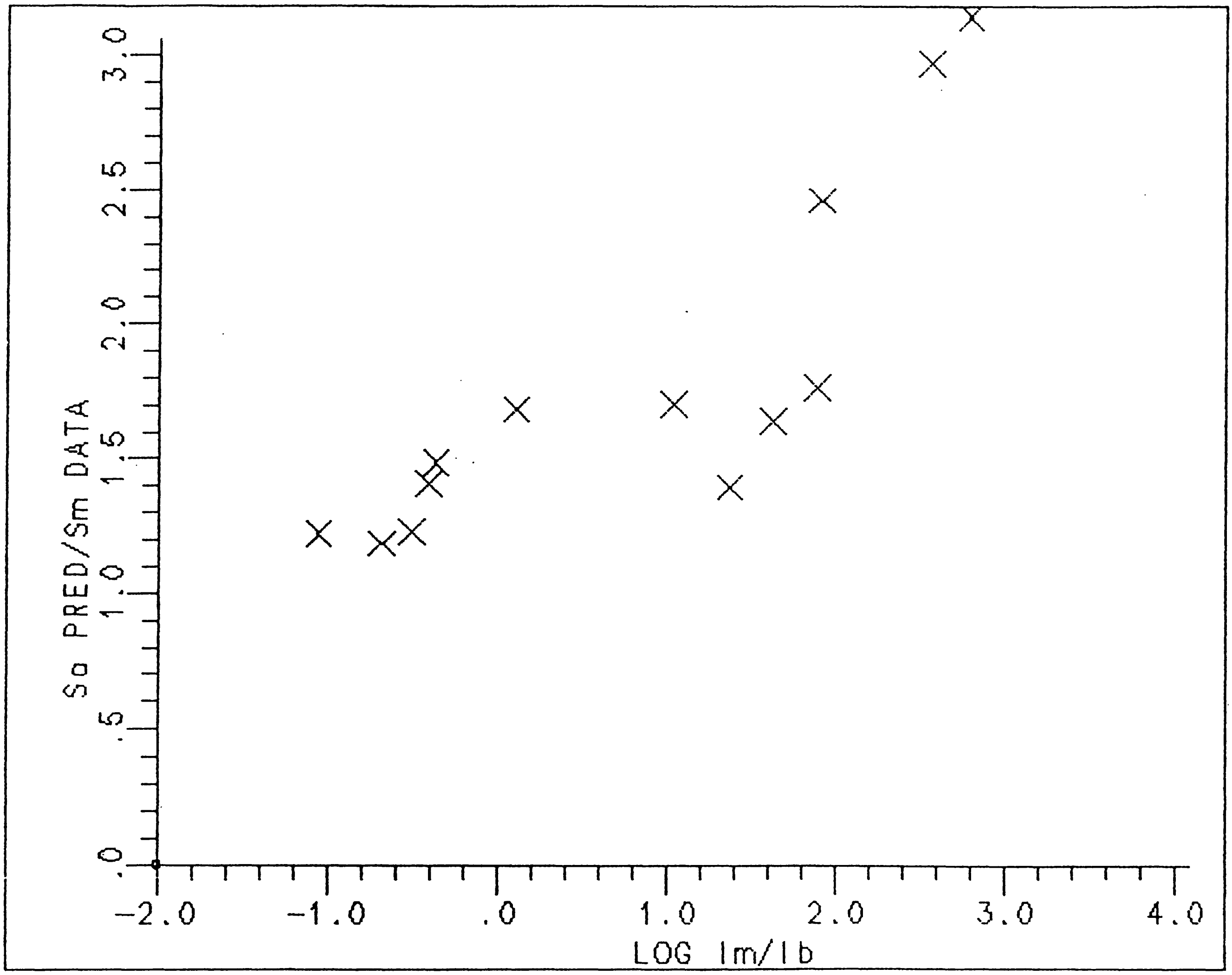

Figure 13. UDKHDEN Predictions of Dilution at Maximum Height of Rise for Horizontal Buoyant Jets in Stratified Ambient Fluid.

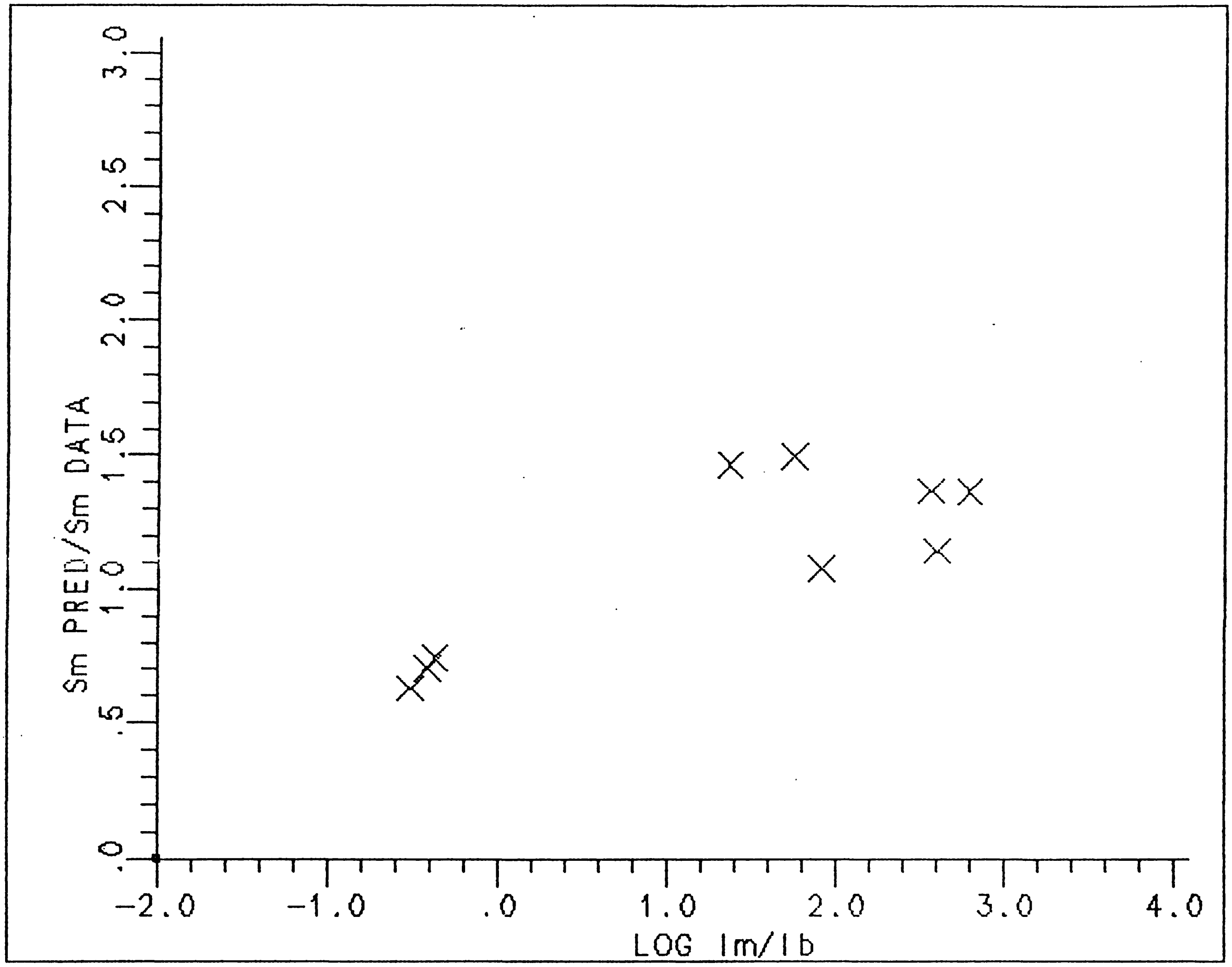

Figure 14. UM Model Predictions of Dilution at Maximum Height of Rise for Horizontal Buoyant Jets in Stratified Ambient Fluid.

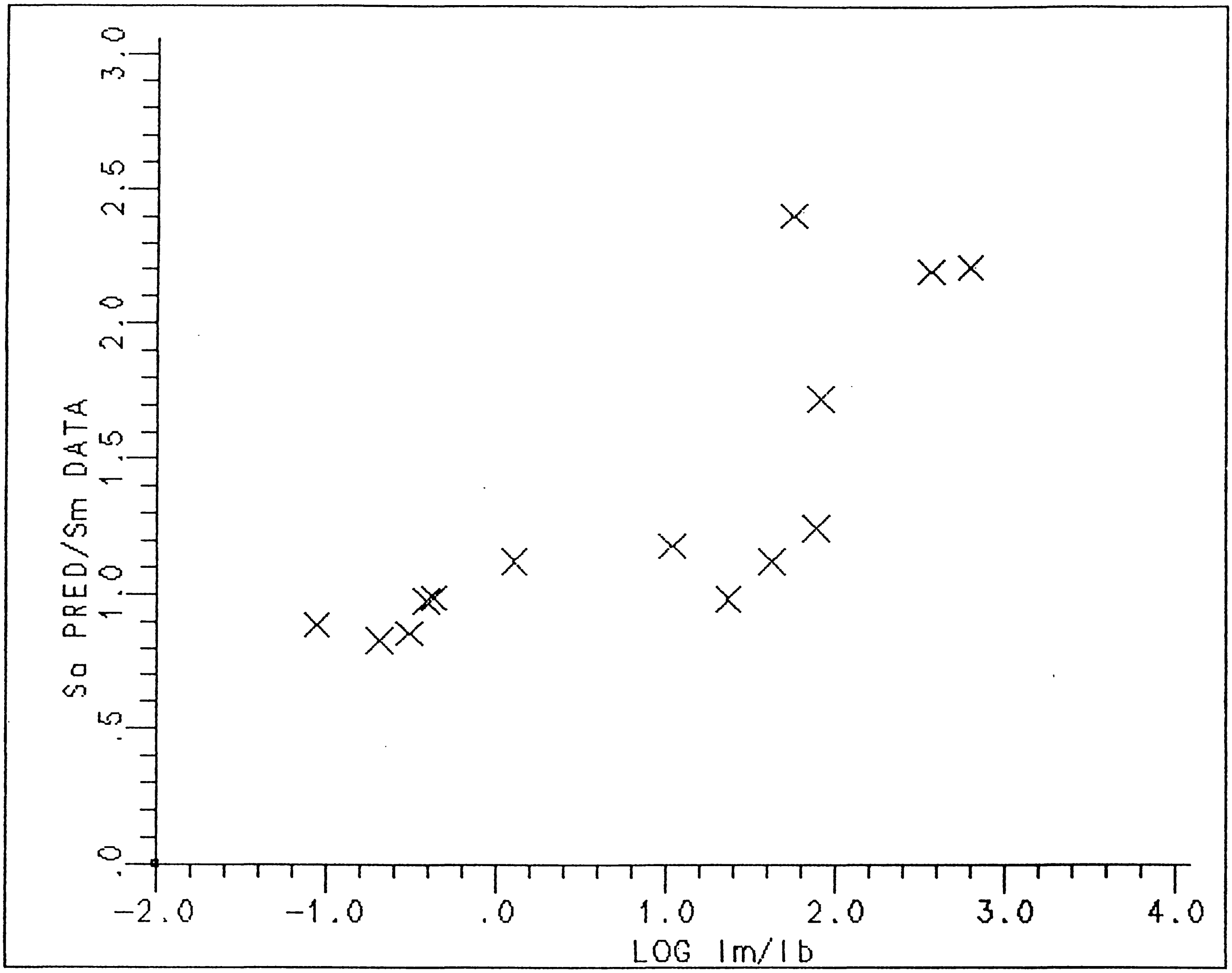

Figure 15. UDKHDEN Predictions of Dilution at Trapping Level for Horizontal Buoyant Jets in Stratified Ambient Fluid.

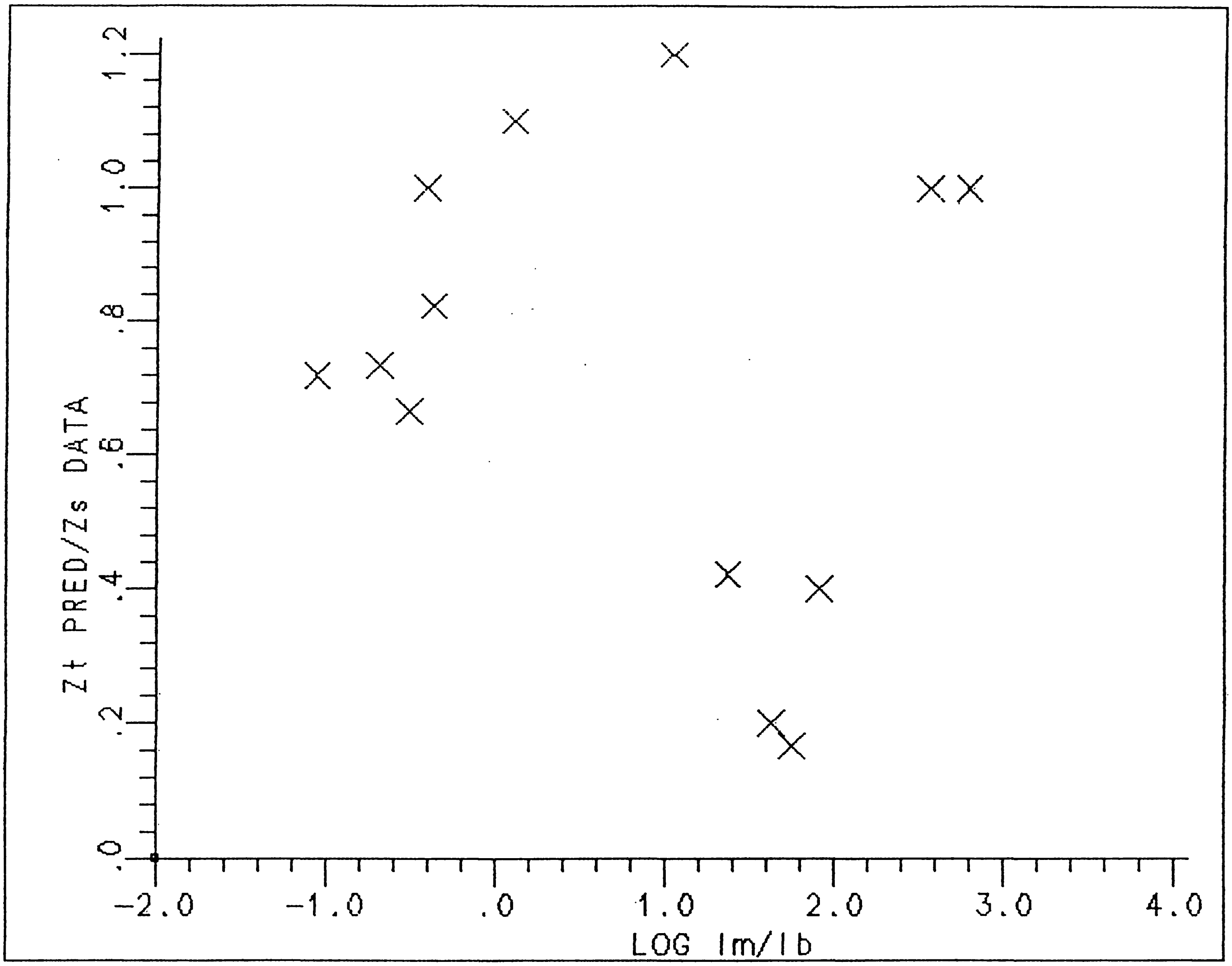

Figure 16. UDKHDEN Predictions of Trapping Level for Horizontal Buoyant Jets in Stratified Ambient Fluid.

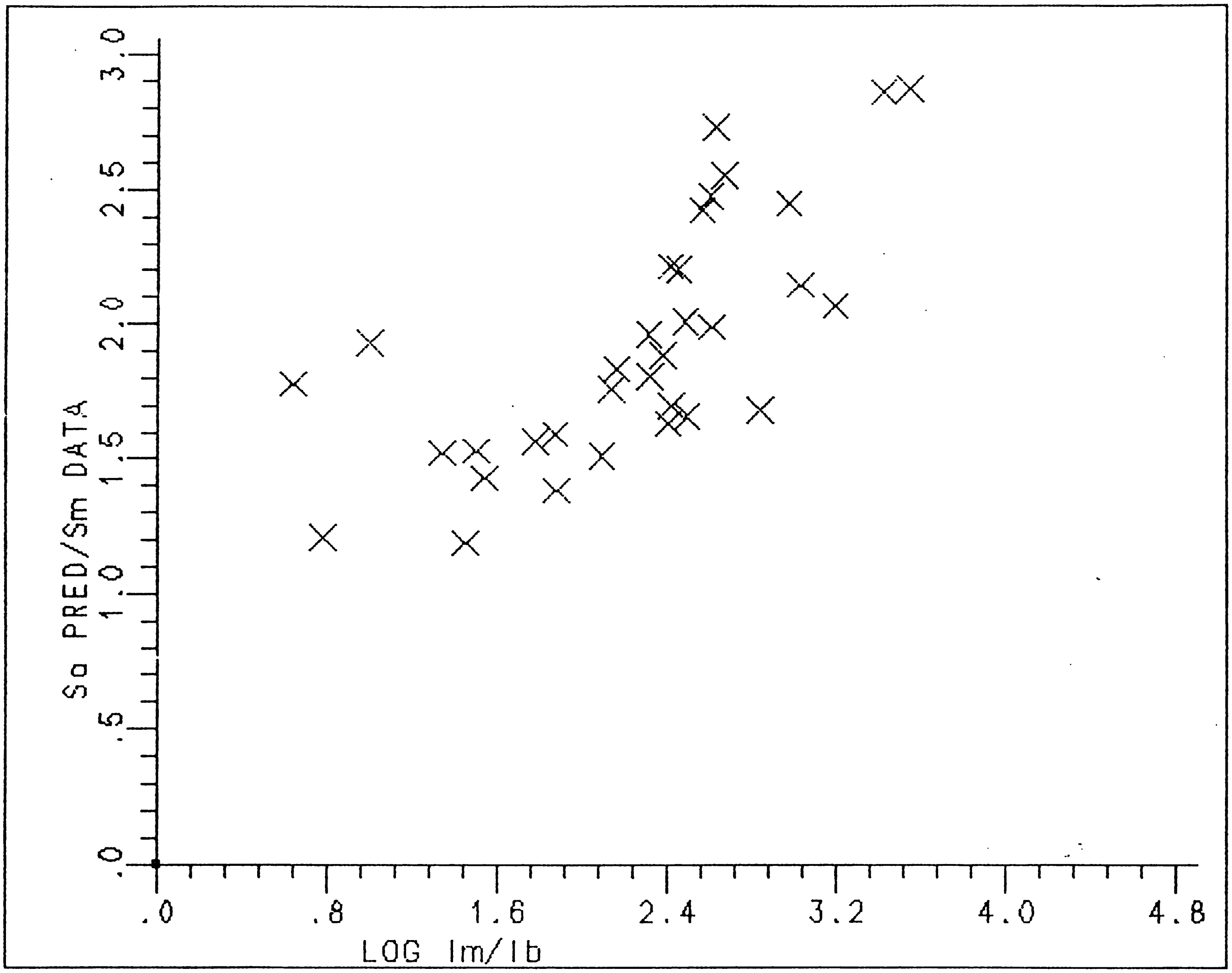

Figure 17. UDKHDEN Predictions of Dilution at Maximum Height of Rise for Diffuser Discharges in Stratified Ambient Fluid.

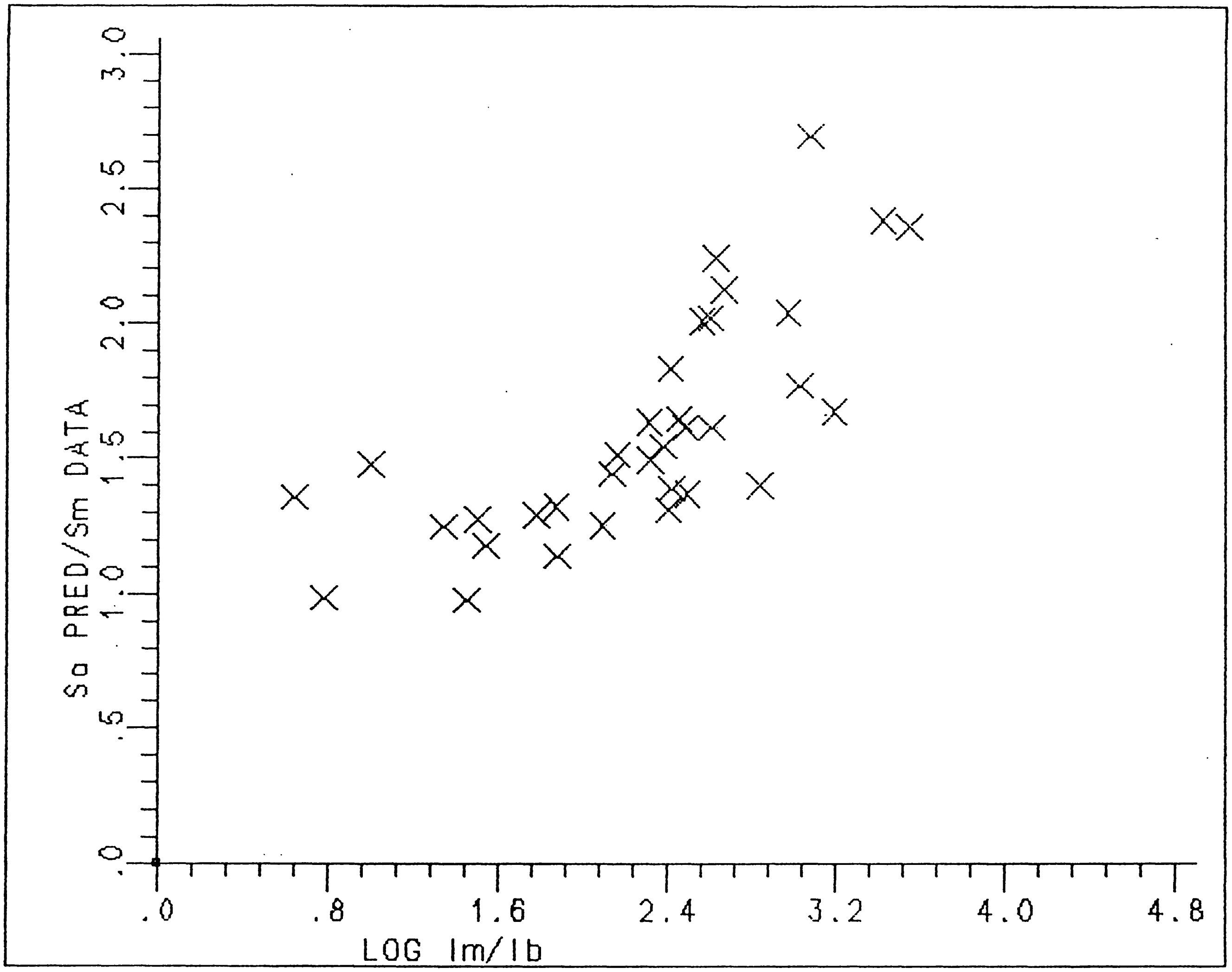

Figure 18. UDKHDEN Predictions of Dilution at Trapping Level for Diffuser Discharges in Stratified Ambient Fluid.

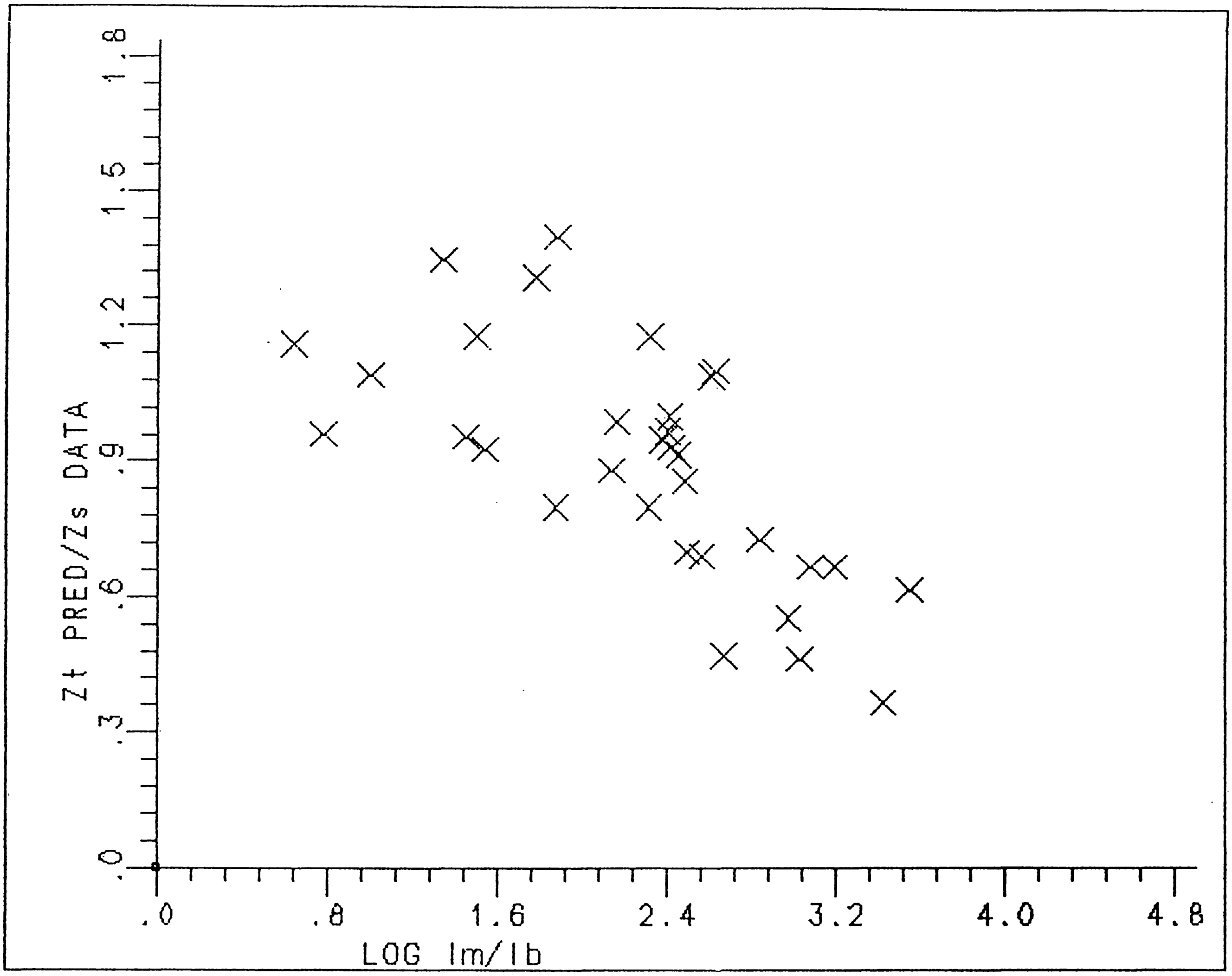

Figure 19. UDKHDEN Predictions of Trapping Level for Diffuser Discharges in Stratified Ambient Fluid.

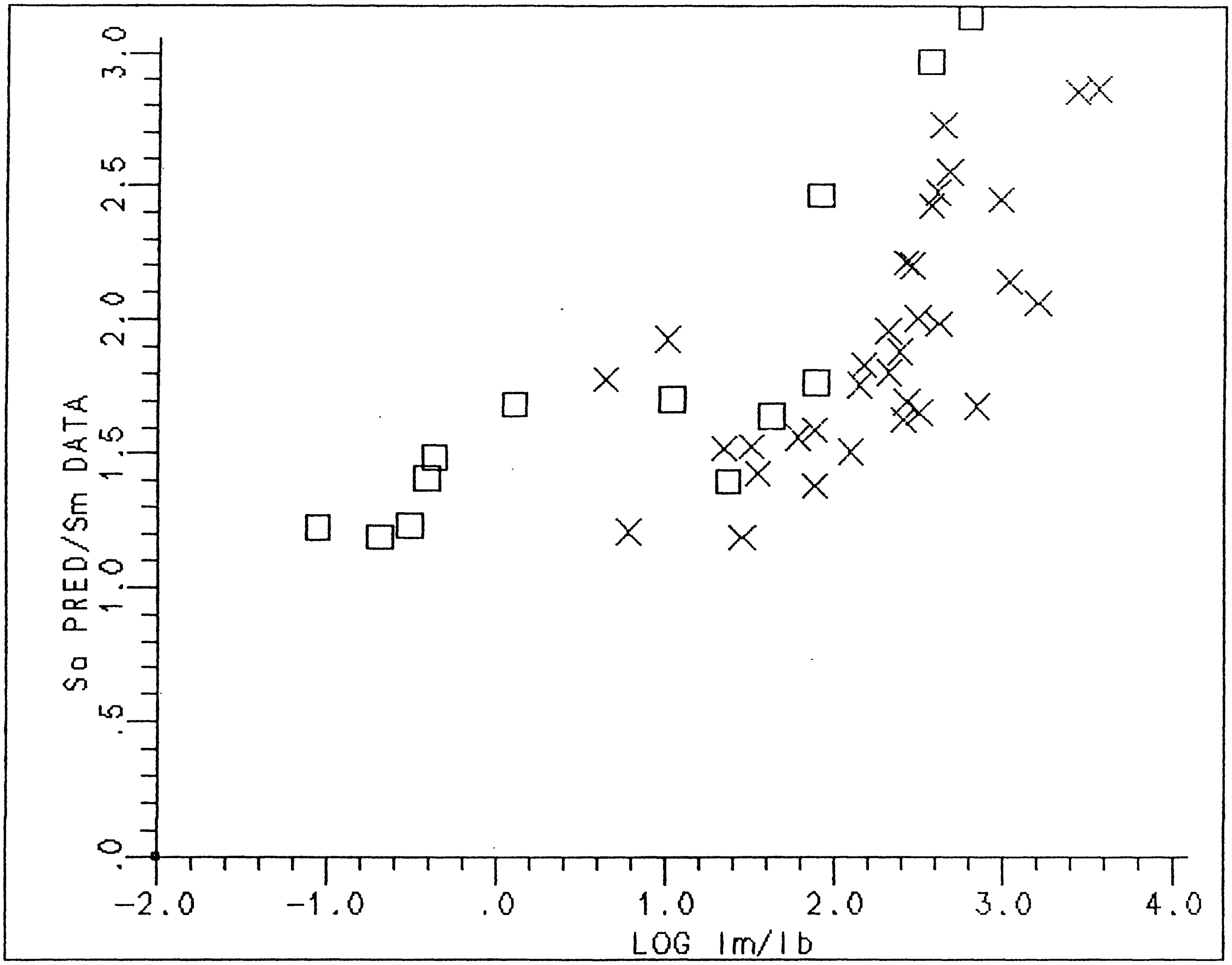

Figure 20. Comparison of UDKHDEN Predictions of Dilution at Maximum Height of Rise for Horizontal Round Buoyant Jets and Diffuser Discharges in Stratified Ambient Fluid.

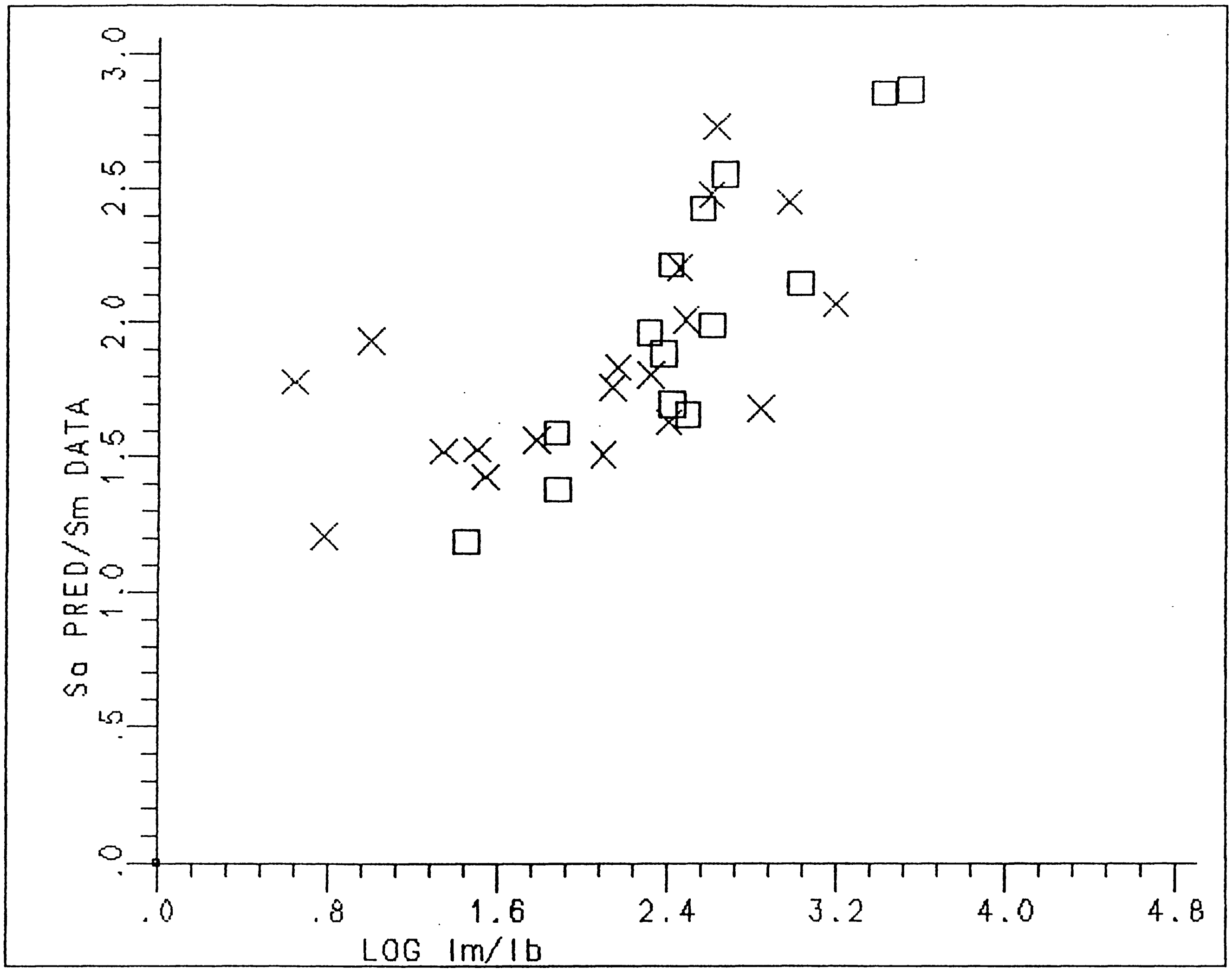

Figure 21. Comparison of UDKHDEN Predictions of Dilution at Maximum Height of Rise from Single and Double Sided Diffuser Discharges in Stratified Ambient Fluid.

APPENDIX 1

LISTING OF UDKHDEN COMPUTER OUTPUTS

A. UNSTRATIFIED AMBIENT FLUIDS

```
1
  UNIVERSAL DATA FILE: unstrat.dat

  #1 Simulation of Wong's Unstratified Flow data,Run 1005A
  0 1 0 0 0 0 0
 0.0000805          1  .00511  90.         2.
        0.       90.       1000.
          2    1.0000        0.
      00.00 1.00389    0.0
    3.00   1.00389     0.0
1
                                            PROGRAM UDKHDEN
                           SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
                           AMBIENT CURRENTS AND VERTICAL GRADIENTS.   AUG 1985

    UNIVERSAL DATA FILE: unstrat.dat
    CASE I.D.  #1 Simulation of Wong's Unstratified Flow data,Run 1005A

          SINGLE PORT DISCHARGE CASE
    DISCHARGE=  .0001 CU-M/S  DENSITY=1.00000 G/CM3  ** DIAMETER=  .0051-M
    ** NUMBER OF PORTS=   1  ** SPACING=1000.00-M  ** DEPTH=   2.00-M
0          AMBIENT STRATIFICATION PROFILE
     DEPTH (M)    DENSITY (G/CM3)   VELOCITY (M/S)
          .00        1.00389           .000
         3.00        1.00389           .000
0   FROUDE NO=281.23,  PORT SPACING/PORT DIA= 195694.72,
+                                                          STARTING LENGTH=     .030

    ALL LENGTHS ARE IN METERS-TIME IN SEC.  FIRST LINE ARE INITIAL CONDITIONS.
      X        Y        Z       TH1      TH2      WIDTH     DUCL     DRHO     DCCL       TIME   DILUTION

       .00      .00      .00   90.00    90.00      .01    1.000    1.000    1.000        .00     1.00
      0.00     0.00      .03   90.00    90.00      .01    1.000    1.000    1.000        .01     1.93
      0.00     0.00      .07 ✓ 90.00    90.00      .05     .306     .305     .305        .03     6.31
      0.00     0.00      .11   90.00    90.00      .08     .180     .180     .180        .08    10.69
      0.00     0.00      .15   90.00    90.00      .11     .128     .128     .128        .14    15.07
      0.00     0.00      .19   90.00    90.00      .14     .099     .099     .099        .24    19.46 ✓
      0.00     0.00      .23   90.00    90.00      .17     .081     .081     .081        .35    23.85
      0.00     0.00      .27   90.00    90.00      .20     .069     .068     .068        .49    28.24
      0.00     0.00      .32 ✓ 90.00    90.00      .24     .060     .059     .059        .66    32.64 ✓
      0.00     0.00      .36   90.00    90.00      .27     .053     .052     .052        .84    37.05
      0.00     0.00      .40   90.00    90.00      .30     .047     .046     .046       1.05    41.47
      0.00     0.00      .44 ✓ 90.00    90.00      .33     .043     .042     .042       1.28    45.90 ✓
      0.00     0.00      .52   90.00    90.00      .39     .036     .035     .035       1.81    54.78
      0.00     0.00      .60   90.00    90.00      .45     .032     .030     .030       2.43    63.71
      0.00     0.00      .68 ✓ 90.00    90.00      .51     .028     .026     .026       3.13    72.69 ✓
      0.00     0.00      .77   90.00    90.00      .57     .025     .024     .024       3.91    81.73
      0.00     0.00      .85   90.00    90.00      .63     .023     .021     .021       4.77    90.83
      0.00     0.00      .93 ✓ 90.00    90.00      .69     .021     .019     .019       5.71   100.01
      0.00     0.00     1.01   90.00    90.00      .75     .020     .018     .018       6.73   109.26
      0.00     0.00     1.09   90.00    90.00      .80     .019     .016     .016       7.81   118.59
      0.00     0.00     1.17   90.00    90.00      .86     .018     .015     .015       8.96   128.01
      0.00     0.00     1.26   90.00    90.00      .92     .017     .014     .014      10.18   137.52
      0.00     0.00     1.42   90.00    90.00     1.02     .015     .012     .012      12.80   156.82
      0.00     0.00     1.58   90.00    90.00     1.13     .014     .011     .011      15.65   176.52
      0.00     0.00     1.75   90.00    90.00     1.23     .013     .010     .010      18.70   196.65
```

```
    PLUME HAS REACHED WATER SURFACE

    DILUTION= 228.73
1
  UNIVERSAL DATA FILE: unstrat.dat

  #2 Simulation of Wong's Unstratified Flow data, Run 0210-1
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 0.0000666         1  .00511  90.         2.
        0.      90.       1000.
         2    1.0000        0.
      00.00 1.01112    0.0
    3.00   1.01112     0.
1
                                               PROGRAM UDKHDEN
                              SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
                              AMBIENT CURRENTS AND VERTICAL GRADIENTS.   AUG 1985

    UNIVERSAL DATA FILE: unstrat.dat
    CASE I.D.  #2 Simulation of Wong's Unstratified Flow data, Run 0210-1

          SINGLE PORT DISCHARGE CASE
    DISCHARGE=  .0001 CU-M/S  DENSITY=1.00000 G/CM3  ** DIAMETER=  .0051-M
    ** NUMBER OF PORTS=   1  ** SPACING=1000.00-M  ** DEPTH=   2.00-M
0          AMBIENT STRATIFICATION PROFILE
     DEPTH (M)    DENSITY (G/CM3)   VELOCITY (M/S)
          .00        1.01112            .000
         3.00        1.01112            .000
0   FROUDE NO=137.62,  PORT SPACING/PORT DIA= 195694.72,
+                                                             STARTING LENGTH=     .030

    ALL LENGTHS ARE IN METERS-TIME IN SEC.  FIRST LINE ARE INITIAL CONDITIONS.
      X        Y        Z       TH1      TH2      WIDTH     DUCL      DRHO      DCCL       TIME    DILUTION

      .00      .00      .00   90.00    90.00      .01     1.000     1.000     1.000       .00      1.00
     0.00     0.00      .03   90.00    90.00      .01     1.000     1.000     1.000       .01      1.93
     0.00     0.00      .07✓  90.00    90.00      .05      .306      .305      .305       .04      6.31
     0.00     0.00      .11   90.00    90.00      .08      .181      .180      .180       .09     10.69
     0.00     0.00      .15   90.00    90.00      .11      .129      .128      .128       .17     15.09
     0.00     0.00      .19✓  90.00    90.00      .14      .101      .099      .099       .29     19.50
     0.00     0.00      .23   90.00    90.00      .17      .083      .080      .080       .42     23.93
     0.00     0.00      .27   90.00    90.00      .20      .070      .068      .068       .59     28.38
     0.00     0.00      .32✓  90.00    90.00      .23      .062      .059      .059       .78     32.85
     0.00     0.00      .36   90.00    90.00      .26      .055      .052      .052      1.00     37.36
     0.00     0.00      .40   90.00    90.00      .29      .050      .046      .046      1.24     41.89
     0.00     0.00      .44✓  90.00    90.00      .32      .045      .041      .041      1.50     46.46
     0.00     0.00      .52   90.00    90.00      .38      .039      .035      .035      2.10     55.71
     0.00     0.00      .60   90.00    90.00      .44      .035      .030      .030      2.78     65.13
     0.00     0.00      .68✓  90.00    90.00      .49      .032      .026      .026      3.54     74.74
     0.00     0.00      .77   90.00    90.00      .54      .029      .023      .023      4.37     84.55
     0.00     0.00      .85   90.00    90.00      .59      .027      .020      .020      5.26     94.58
     0.00     0.00      .93✓  90.00    90.00      .64      .026      .018      .018      6.21    104.83
     0.00     0.00     1.01   90.00    90.00      .69      .024      .017      .017      7.22    115.31
     0.00     0.00     1.09   90.00    90.00      .74      .023      .015      .015      8.27    126.04
     0.00     0.00     1.17   90.00    90.00      .79      .022      .014      .014      9.36    137.01
```

```
      0.00     0.00     1.42   90.00    90.00       .92      .021      .011      .011      12.88    171.43
      0.00     0.00     1.58   90.00    90.00      1.01      .020      .010      .010      15.39    195.65
      0.00     0.00     1.75   90.00    90.00      1.09      .019      .009      .009      18.00    220.89
      0.00     0.00     1.91   90.00    90.00      1.17      .018      .008      .008      20.72    247.17

    PLUME HAS REACHED WATER SURFACE

    DILUTION= 262.06
1
  UNIVERSAL DATA FILE: unstrat.dat

  #3 Simulation of Wong's Unstratified Flow data, Run 0215-1
  0 1 0 0 0 0 0
 0.0000296          1  .01060  90.         2.
        0.       90.       1000.
         2    1.0000         0.
      00.00 1.00961    0.0
    3.00   1.00961     0.0
1
                                  PROGRAM UDKHDEN
                        SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
                        AMBIENT CURRENTS AND VERTICAL GRADIENTS.   AUG 1985

    UNIVERSAL DATA FILE: unstrat.dat
    CASE I.D.  #3 Simulation of Wong's Unstratified Flow data, Run 0215-1

        SINGLE PORT DISCHARGE CASE
    DISCHARGE= 0.0000 CU-M/S  DENSITY=1.00000 G/CM3  ** DIAMETER=  .0106-M
    ** NUMBER OF PORTS=   1  ** SPACING=1000.00-M  ** DEPTH=   2.00-M
0        AMBIENT STRATIFICATION PROFILE
     DEPTH (M)    DENSITY (G/CM3)   VELOCITY (M/S)
        .00        1.00961            .000
       3.00        1.00961            .000
0   FROUDE NO= 10.62,  PORT SPACING/PORT DIA=  94339.62,
+                                                        STARTING LENGTH=     .059

    ALL LENGTHS ARE IN METERS-TIME IN SEC.  FIRST LINE ARE INITIAL CONDITIONS.
      X        Y        Z       TH1      TH2      WIDTH      DUCL      DRHO      DCCL       TIME   DILUTION

      .00      .00      .00   90.00    90.00       .01     1.000     1.000     1.000        .00      1.00
     0.00     0.00      .06✓  90.00    90.00       .03     1.000      .934      .934        .18      2.06✓
     0.00     0.00      .14   90.00    90.00       .09      .376      .282      .282        .65      6.82
     0.00     0.00      .23✓  90.00    90.00       .14      .278      .157      .157       1.45     12.24✓
     0.00     0.00      .31   90.00    90.00       .18      .240      .104      .104       2.44     18.47
     0.00     0.00      .40✓  90.00    90.00       .23      .219      .075      .075       3.55     25.52✓
     0.00     0.00      .48   90.00    90.00       .27      .205      .058      .058       4.74     33.37
     0.00     0.00      .57✓  90.00    90.00       .31      .194      .046      .046       6.01     42.00✓
     0.00     0.00      .65   90.00    90.00       .35      .186      .037      .037       7.35     51.38
     0.00     0.00      .74✓  90.00    90.00       .39      .179      .031      .031       8.74     61.48✓
     0.00     0.00      .82   90.00    90.00       .43      .173      .027      .027      10.18     72.28
     0.00     0.00      .91✓  90.00    90.00       .47      .168      .023      .023      11.66     83.77✓
     0.00     0.00     1.08   90.00    90.00       .55      .159      .018      .018      14.76    108.71
     0.00     0.00     1.25   90.00    90.00       .63      .152      .014      .014      18.02    136.17
     0.00     0.00     1.42   90.00    90.00       .71      .146      .012      .012      21.43    166.04
     0.00     0.00     1.59   90.00    90.00       .78      .141      .010      .010      24.96    198.23
     0.00     0.00     1.76   90.00    90.00       .86      .136      .008      .008      28.61    232.65
```

```
    PLUME HAS REACHED WATER SURFACE

    DILUTION= 285.94
1
  UNIVERSAL DATA FILE: unstrat.dat

  #4 Simulation of Wong's Unstratified Flow data, Run 0208-1
  0 1 0 0 0 0 0
 0.0000653         1  .01060  90.        2.
        0.       90.       1000.
         2    1.0000        0.
     00.00 1.02280    0.0
    3.00   1.02280    0.0
1
                                              PROGRAM UDKHDEN
                           SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
                           AMBIENT CURRENTS AND VERTICAL GRADIENTS.   AUG 1985

    UNIVERSAL DATA FILE: unstrat.dat
    CASE I.D.  #4 Simulation of Wong's Unstratified Flow data, Run 0208-1

          SINGLE PORT DISCHARGE CASE
    DISCHARGE=  .0001 CU-M/S  DENSITY=1.00000 G/CM3  ** DIAMETER=  .0106-M
    ** NUMBER OF PORTS=   1  ** SPACING=1000.00-M  ** DEPTH=   2.00-M
0           AMBIENT STRATIFICATION PROFILE
     DEPTH (M)    DENSITY (G/CM3)   VELOCITY (M/S)
          .00        1.02280           .000
         3.00        1.02280           .000
0   FROUDE NO= 15.20,  PORT SPACING/PORT DIA=  94339.62,
+                                                        STARTING LENGTH=     .060

.   ALL LENGTHS ARE IN METERS-TIME IN SEC.  FIRST LINE ARE INITIAL CONDITIONS.
      X        Y        Z      TH1      TH2     WIDTH     DUCL     DRHO     DCCL       TIME    DILUTION

      .00      .00      .00    90.00    90.00      .01    1.000    1.000    1.000        .00      1.00
     0.00     0.00      .06    90.00    90.00      .03    1.000     .967     .967        .08      1.99✓
     0.00     0.00      .15    90.00    90.00      .09     .343     .293     .293        .31      6.56
     0.00     0.00      .23    90.00    90.00      .15     .236     .167     .167        .72     11.52✓
     0.00     0.00      .32    90.00    90.00      .19     .195     .113     .113       1.26     16.99
     0.00     0.00      .40    90.00    90.00      .24     .175     .084     .084       1.88     23.03✓
     0.00     0.00      .48    90.00    90.00      .28     .161     .065     .065       2.57     29.64
     0.00     0.00      .57    90.00    90.00      .33     .152     .052     .052       3.30     36.83✓
     0.00     0.00      .65    90.00    90.00      .37     .145     .043     .043       4.07     44.57
     0.00     0.00      .74    90.00    90.00      .41     .139     .036     .036       4.88     52.87✓
     0.00     0.00      .82    90.00    90.00      .45     .135     .031     .031       5.72     61.70
     0.00     0.00      .91    90.00    90.00      .49     .131     .027     .027       6.58     71.06✓
     0.00     0.00     1.08    90.00    90.00      .57     .124     .021     .021       8.38     91.28
     0.00     0.00     1.25    90.00    90.00      .65     .118     .017     .017      10.28    113.45
     0.00     0.00     1.42    90.00    90.00      .73     .114     .014     .014      12.26    137.49
     0.00     0.00     1.59    90.00    90.00      .81     .110     .012     .012      14.31    163.33
     0.00     0.00     1.76    90.00    90.00      .89     .106     .010     .010      16.43    190.92
     0.00     0.00     1.93    90.00    90.00      .96     .103     .009     .009      18.62    220.19

    PLUME HAS REACHED WATER SURFACE
```

```
1
  UNIVERSAL DATA FILE: unstrat.dat

  #5 Simulation of Wong's Unstratified Flow data, Run 0210-2
  0 1 0 0 0 0 0
 0.0000445         1  .01060  90.         2.
        0.       90.       1000.
         2    1.0000       0.
      00.00 1.01160    0.0
    3.00   1.01160     0.0
1
                                      PROGRAM UDKHDEN
                         SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
                         AMBIENT CURRENTS AND VERTICAL GRADIENTS.   AUG 1985

    UNIVERSAL DATA FILE: unstrat.dat
    CASE I.D.  #5 Simulation of Wong's Unstratified Flow data, Run 0210-2

          SINGLE PORT DISCHARGE CASE
    DISCHARGE= 0.0000 CU-M/S  DENSITY=1.00000 G/CM3  ** DIAMETER=  .0106-M
    ** NUMBER OF PORTS=   1  ** SPACING=1000.00-M  ** DEPTH=   2.00-M
0          AMBIENT STRATIFICATION PROFILE
     DEPTH (M)    DENSITY (G/CM3)   VELOCITY (M/S)
          .00        1.01160             .000
         3.00        1.01160             .000
0   FROUDE NO= 14.53,  PORT SPACING/PORT DIA=  94339.62,
+                                                         STARTING LENGTH=     .060

    ALL LENGTHS ARE IN METERS-TIME IN SEC.  FIRST LINE ARE INITIAL CONDITIONS.
      X        Y        Z       TH1      TH2      WIDTH     DUCL      DRHO      DCCL        TIME    DILUTION

      .00      .00      .00    90.00    90.00       .01     1.000     1.000     1.000        .00      1.00
     0.00     0.00      .06    90.00    90.00       .03     1.000      .964      .964        .12      2.00
     0.00     0.00      .15    90.00    90.00       .09      .346      .292      .292        .45      6.59
     0.00     0.00      .23    90.00    90.00       .15      .240      .166      .166       1.05     11.59
     0.00     0.00      .32    90.00    90.00       .19      .200      .112      .112       1.82     17.14
     0.00     0.00      .40    90.00    90.00       .24      .179      .083      .083       2.72     23.29
     0.00     0.00      .48    90.00    90.00       .28      .166      .064      .064       3.69     30.03
     0.00     0.00      .57    90.00    90.00       .32      .157      .052      .052       4.73     37.38
     0.00     0.00      .65    90.00    90.00       .36      .150      .043      .043       5.83     45.31
     0.00     0.00      .74    90.00    90.00       .40      .144      .036      .036       6.98     53.81
     0.00     0.00      .82    90.00    90.00       .44      .139      .031      .031       8.17     62.86
     0.00     0.00      .91    90.00    90.00       .48      .135      .027      .027       9.40     72.46
     0.00     0.00     1.08    90.00    90.00       .56      .128      .021      .021      11.96     93.21
     0.00     0.00     1.25    90.00    90.00       .64      .122      .017      .017      14.66    115.98
     0.00     0.00     1.42    90.00    90.00       .72      .117      .014      .014      17.47    140.68
     0.00     0.00     1.59    90.00    90.00       .80      .113      .012      .012      20.38    167.24
     0.00     0.00     1.76    90.00    90.00       .88      .110      .010      .010      23.40    195.60
     0.00     0.00     1.93    90.00    90.00       .96      .107      .009      .009      26.51    225.71

    PLUME HAS REACHED WATER SURFACE

    DILUTION= 239.32
```

APPENDIX 1

LISTING OF UDKHDEN COMPUTER OUTPUTS

B. VERTICAL JETS IN STRATIFIED AMBIENT FLUIDS

```
1
  UNIVERSAL DATA FILE: STRATVER1.DAT

  #1 Simulation of Wong's Stratified Flow data, Run 1112-82
  0 1 0 0 0 0 0
 0.0000307         1  .01480  90.        2.
       0.       90.       1000.
        2    1.0000        0.
     00.00 0.99997    0.0
    10.0   1.042495     0.
1
                                          PROGRAM UDKHDEN
                          SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
                          AMBIENT CURRENTS AND VERTICAL GRADIENTS.   AUG 1985

    UNIVERSAL DATA FILE: STRATVER1.DAT
    CASE I.D.  #1 Simulation of Wong's Stratified Flow data, Run 1112-82

         SINGLE PORT DISCHARGE CASE
    DISCHARGE= 0.0000 CU-M/S  DENSITY=1.00000 G/CM3  ** DIAMETER=  .0148-M
    ** NUMBER OF PORTS=   1  ** SPACING=1000.00-M  ** DEPTH=   2.00-M
0          AMBIENT STRATIFICATION PROFILE
     DEPTH (M)    DENSITY (G/CM3)   VELOCITY (M/S)
         .00          .99997            .000
       10.00        1.04249             .000
0   FROUDE NO=  5.09,  PORT SPACING/PORT DIA=  67567.57,
+                                                     STARTING LENGTH=     .070

    ALL LENGTHS ARE IN METERS-TIME IN SEC.  FIRST LINE ARE INITIAL CONDITIONS.
      X       Y       Z      TH1     TH2     WIDTH     DUCL     DRHO     DCCL      TIME   DILUTION

     .00     .00     .00   90.00   90.00      .01    1.000    1.000    1.000       .00     1.00
    0.00    0.00     .08   90.00   90.00      .05    1.000     .727     .761       .44     2.48
    0.00    0.00     .20   90.00   90.00      .12     .486     .150     .233      1.48     8.09

    PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

    0.00    0.00     .31   90.00   90.00      .20     .325    -.006     .128      3.15    14.78

    PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT

    TRAPPING LEVEL=   1.69 METERS BELOW SURFACE,  DILUTION=  14.43
1
  UNIVERSAL DATA FILE: STRATVER1.DAT

  #2 Simulation of Wong's Stratified Flow data,Run 0406-82
  0 1 0 0 0 0 0
 0.0000275         1  .01480  90.        2.
       0.       90.       1000.
        2    1.0000        0.
     00.00 1.00698    0.0
    10.00 1.032472    0.0
1
                                          PROGRAM UDKHDEN
                          SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
                          AMBIENT CURRENTS AND VERTICAL GRADIENTS.   AUG 1985
```

```
     UNIVERSAL DATA FILE: STRATVER1.DAT
     CASE I.D.  #2 Simulation of Wong's Stratified Flow data,Run 0406-82

           SINGLE PORT DISCHARGE CASE
     DISCHARGE= 0.0000 CU-M/S  DENSITY=1.00000 G/CM3  ** DIAMETER=  .0148-M
     ** NUMBER OF PORTS=   1  ** SPACING=1000.00-M  ** DEPTH=   2.00-M
0           AMBIENT STRATIFICATION PROFILE
      DEPTH (M)    DENSITY (G/CM3)   VELOCITY (M/S)
          .00        1.00698             .000
        10.00        1.03247             .000
0    FROUDE NO=  3.82,  PORT SPACING/PORT DIA=  67567.57,
+                                                        STARTING LENGTH=     .062

     ALL LENGTHS ARE IN METERS-TIME IN SEC.  FIRST LINE ARE INITIAL CONDITIONS.
       X        Y        Z       TH1      TH2      WIDTH      DUCL      DRHO      DCCL       TIME    DILUTION

       .00      .00      .00    90.00    90.00      .01      1.000     1.000     1.000       .00      1.00
      0.00     0.00      .07    90.00    90.00      .05      1.000      .636      .649       .46      2.94
      0.00     0.00      .19    90.00    90.00      .12       .590      .169      .204      1.50      9.36
      0.00     0.00      .31    90.00    90.00      .18       .461      .053      .108      2.92     17.62

     PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

      0.00     0.00      .43    90.00    90.00      .26       .341     -.005      .071      4.77     27.03
      0.00     0.00      .55    90.00    90.00      .47       .140     -.046      .053      7.82     35.93

     PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT

     TRAPPING LEVEL=   1.58 METERS BELOW SURFACE,  DILUTION=  26.07
1
   UNIVERSAL DATA FILE: STRATVER1.DAT

   #3 Simulation of Wong's Stratified Flow data, Run 1102-82
   0 1 0 0 0 0 0
  0.0000260          1  .01060  90.         2.
         0.       90.       1000.
           2    1.0000        0.
       00.00 0.99374     0.0
      10.0   1.046978     0.0
1
                                       PROGRAM UDKHDEN
                          SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
                          AMBIENT CURRENTS AND VERTICAL GRADIENTS.   AUG 1985

     UNIVERSAL DATA FILE: STRATVER1.DAT
     CASE I.D.  #3 Simulation of Wong's Stratified Flow data, Run 1102-82

           SINGLE PORT DISCHARGE CASE
     DISCHARGE= 0.0000 CU-M/S  DENSITY=1.00000 G/CM3  ** DIAMETER=  .0106-M
     ** NUMBER OF PORTS=   1  ** SPACING=1000.00-M  ** DEPTH=   2.00-M
0           AMBIENT STRATIFICATION PROFILE
      DEPTH (M)    DENSITY (G/CM3)   VELOCITY (M/S)
          .00         .99374             .000
        10.00        1.04698             .000
0    FROUDE NO= 13.80,  PORT SPACING/PORT DIA=  94339.62,
+                                                        STARTING LENGTH=     .059
```

```
   ALL LENGTHS ARE IN METERS-TIME IN SEC.  FIRST LINE ARE INITIAL CONDITIONS.
     X        Y         Z        TH1      TH2      WIDTH      DUCL      DRHO      DCCL       TIME    DILUTION

      .00      .00      .00    90.00    90.00       .01     1.000     1.000     1.000        .00      1.00
     0.00     0.00      .06    90.00    90.00       .03     1.000      .862      .932        .21      2.00
     0.00     0.00      .15    90.00    90.00       .09      .337      .134      .284        .77      6.58

   PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

     0.00     0.00      .23    90.00    90.00       .16      .195     -.079      .165       1.91     11.32
     0.00     0.00      .31    90.00    90.00       .65      .016     -.232      .121       4.70     15.38

   PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT

   TRAPPING LEVEL=   1.81 METERS BELOW SURFACE,  DILUTION=   9.25
1
 UNIVERSAL DATA FILE: STRATVER1.DAT

 #4 Simulation of Wong's Stratified Flow data, Run 1103-82
 0 1 0 0 0 0 0
0.0000234         1  .01480  90.        2.
       0.      90.       1000.
        2   1.0000        0.
     00.00 0.99492    0.0
    10.0   1.033777     0.0
1
                                   PROGRAM UDKHDEN
                         SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
                         AMBIENT CURRENTS AND VERTICAL GRADIENTS.   AUG 1985

   UNIVERSAL DATA FILE: STRATVER1.DAT
   CASE I.D.  #4 Simulation of Wong's Stratified Flow data, Run 1103-82

        SINGLE PORT DISCHARGE CASE
   DISCHARGE= 0.0000 CU-M/S  DENSITY=1.00000 G/CM3  ** DIAMETER=  .0148-M
   ** NUMBER OF PORTS=   1  ** SPACING=1000.00-M  ** DEPTH=   2.00-M
0        AMBIENT STRATIFICATION PROFILE
    DEPTH (M)    DENSITY (G/CM3)   VELOCITY (M/S)
         .00           .99492            .000
       10.00          1.03378            .000
0  FROUDE NO=  6.88,  PORT SPACING/PORT DIA=  67567.57,
+                                                       STARTING LENGTH=     .075

   ALL LENGTHS ARE IN METERS-TIME IN SEC.  FIRST LINE ARE INITIAL CONDITIONS.
     X        Y         Z        TH1      TH2      WIDTH      DUCL      DRHO      DCCL       TIME    DILUTION

      .00      .00      .00    90.00    90.00       .01     1.000     1.000     1.000        .00      1.00
     0.00     0.00      .08    90.00    90.00       .04     1.000      .718      .822        .59      2.21
     0.00     0.00      .20    90.00    90.00       .13      .378      .008      .253       2.16      7.20

   PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

     0.00     0.00      .32    90.00    90.00       .98      .011     -.263      .153       7.43     11.87

   PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT
```

```
1
  UNIVERSAL DATA FILE: STRATVER1.DAT

   #5 Simulation of Wong's Stratified Flow data,Run 1111-82
   0 1 0 0 0 0 0
  0.0000419          1  .01480  90.         2.
         0.       90.       1000.
          2    1.0000        0.
       00.00 0.99952     0.0
     10.0   1.041836      0.0
1
                                   PROGRAM UDKHDEN
                        SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
                        AMBIENT CURRENTS AND VERTICAL GRADIENTS.   AUG 1985

    UNIVERSAL DATA FILE: STRATVER1.DAT
    CASE I.D.  #5 Simulation of Wong's Stratified Flow data,Run 1111-82

        SINGLE PORT DISCHARGE CASE
    DISCHARGE= 0.0000 CU-M/S  DENSITY=1.00000 G/CM3  ** DIAMETER=  .0148-M
    ** NUMBER OF PORTS=   1  ** SPACING=1000.00-M  ** DEPTH=   2.00-M
0          AMBIENT STRATIFICATION PROFILE
     DEPTH (M)    DENSITY (G/CM3)   VELOCITY (M/S)
          .00          .99952            .000
        10.00         1.04184            .000
0   FROUDE NO=  7.16,  PORT SPACING/PORT DIA=  67567.57,
+                                                     STARTING LENGTH=     .077

    ALL LENGTHS ARE IN METERS-TIME IN SEC.  FIRST LINE ARE INITIAL CONDITIONS.
      X       Y       Z      TH1      TH2     WIDTH     DUCL     DRHO     DCCL      TIME   DILUTION

     .00     .00     .00   90.00    90.00      .01    1.000    1.000    1.000       .00     1.00
    0.00    0.00     .08   90.00    90.00      .04    1.000     .814     .854       .33     2.21
    0.00    0.00     .20   90.00    90.00      .12     .416     .170     .259      1.18     7.28
    0.00    0.00     .32   90.00    90.00      .20     .275     .001     .144      2.63    13.09

    PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

    0.00    0.00     .44   90.00    90.00      .39     .103    -.103     .101      5.20    18.68

    PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT

    TRAPPING LEVEL=   1.68 METERS BELOW SURFACE,  DILUTION=  13.12
1
  UNIVERSAL DATA FILE: STRATVER1.DAT

  #6 Simulation of Wong's Stratified Flow data, Run 1105-82
  0 1 0 0 0 0 0
 0.0000161          1  .01480  90.         2.
        0.       90.       1000.
         2    1.0000        0.
      00.00 0.99788    0.0
    10.0   1.031943     0.
1
                                   PROGRAM UDKHDEN
                        SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
```

```
    UNIVERSAL DATA FILE: STRATVER1.DAT
    CASE I.D.  #6 Simulation of Wong's Stratified Flow data, Run 1105-82

          SINGLE PORT DISCHARGE CASE
    DISCHARGE= 0.0000 CU-M/S  DENSITY=1.00000 G/CM3  ** DIAMETER=  .0148-M
    ** NUMBER OF PORTS=   1  ** SPACING=1000.00-M  ** DEPTH=   2.00-M
0          AMBIENT STRATIFICATION PROFILE
     DEPTH (M)    DENSITY (G/CM3)   VELOCITY (M/S)
          .00         .99788            .000
       10.00        1.03194            .000
0   FROUDE NO=  3.59,  PORT SPACING/PORT DIA=  67567.57,
+                                                         STARTING LENGTH=     .059

    ALL LENGTHS ARE IN METERS-TIME IN SEC.  FIRST LINE ARE INITIAL CONDITIONS.
      X       Y       Z      TH1     TH2     WIDTH     DUCL     DRHO     DCCL      TIME   DILUTION

      .00     .00     .00    90.00   90.00     .01     1.000    1.000    1.000        .00     1.00
     0.00    0.00     .07    90.00   90.00     .05     1.000     .577     .620        .77     3.02
     0.00    0.00     .19    90.00   90.00     .12      .553     .078     .198       2.56     9.44

    PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

     0.00    0.00     .31    90.00   90.00     .24      .242    -.086     .112       5.76    16.67

    PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT

    TRAPPING LEVEL=   1.76 METERS BELOW SURFACE,  DILUTION=  12.47
1
  UNIVERSAL DATA FILE: STRATVER1.DAT

  #7 Simulation of Wong's Stratified Flow data, Run 0404-82
  0 1 0 0 0 0 0
 0.0000278          1  .01480  90.         2.
         0.       90.       1000.
          2    1.0000        0.
      00.00 1.00201    0.0
      00.00 1.00201    0.0
1
                                          PROGRAM UDKHDEN
                         SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
                         AMBIENT CURRENTS AND VERTICAL GRADIENTS.   AUG 1985

    UNIVERSAL DATA FILE: STRATVER1.DAT
    CASE I.D.  #7 Simulation of Wong's Stratified Flow data, Run 0404-82

          SINGLE PORT DISCHARGE CASE
    DISCHARGE= 0.0000 CU-M/S  DENSITY=1.00000 G/CM3  ** DIAMETER=  .0148-M
    ** NUMBER OF PORTS=   1  ** SPACING=1000.00-M  ** DEPTH=   2.00-M
0          AMBIENT STRATIFICATION PROFILE
     DEPTH (M)    DENSITY (G/CM3)   VELOCITY (M/S)
          .00        1.00201            .000
       10.00         .00000            .000

   ***********************************************
   * THIS RUN DISCONTINUED  BECAUSE THE INITIAL  *
```

```
   * THE MODEL WILL NOT RUN CORRECTLY.            *
   *********************************************

 UNIVERSAL DATA FILE: stratver2.dat

 #8 Simulation of Wong's Stratified Flow data, Run 0527-82
  0 1 0 0 0 0 0
 0.0000256          1  .00511  90.         2.
        0.       90.       1000.
         2    1.0000        0.
     00.00 1.00934     0.0
    10.0   1.060540     0.0
1
                                              PROGRAM UDKHDEN
                              SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
                              AMBIENT CURRENTS AND VERTICAL GRADIENTS.   AUG 1985

    UNIVERSAL DATA FILE: stratver2.dat
    CASE I.D. #8 Simulation of Wong's Stratified Flow data, Run 0527-82

          SINGLE PORT DISCHARGE CASE
    DISCHARGE= 0.0000 CU-M/S  DENSITY=1.00000 G/CM3  ** DIAMETER=  .0051-M
    ** NUMBER OF PORTS=   1  ** SPACING=1000.00-M  ** DEPTH=   2.00-M
0          AMBIENT STRATIFICATION PROFILE
     DEPTH (M)    DENSITY (G/CM3)   VELOCITY (M/S)
         .00          1.00934            .000
       10.00          1.06054            .000
0   FROUDE NO= 39.86,  PORT SPACING/PORT DIA= 195694.72,
+                                                          STARTING LENGTH=     .029

    ALL LENGTHS ARE IN METERS-TIME IN SEC.  FIRST LINE ARE INITIAL CONDITIONS.
      X        Y        Z      TH1      TH2     WIDTH     DUCL     DRHO     DCCL      TIME   DILUTION

      .00      .00      .00    90.00    90.00     .01    1.000    1.000    1.000       .00      1.00
     0.00     0.00      .03    90.00    90.00     .01    1.000     .984     .992       .02      1.94
     0.00     0.00      .07    90.00    90.00     .05     .311     .287     .303       .09      6.34
     0.00     0.00      .11    90.00    90.00     .08     .189     .152     .178       .23     10.81
     0.00     0.00      .15    90.00    90.00     .11     .139     .089     .125       .44     15.37
     0.00     0.00      .19    90.00    90.00     .14     .111     .050     .096       .70     20.04
     0.00     0.00      .23    90.00    90.00     .16     .093     .022     .077      1.02     24.79

    PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

     0.00     0.00      .27    90.00    90.00     .20     .079    0.000     .065      1.41     29.60
     0.00     0.00      .32    90.00    90.00     .23     .067    -.019     .056      1.86     34.41
     0.00     0.00      .36    90.00    90.00     .27     .054    -.036     .049      2.40     39.11
     0.00     0.00      .40    90.00    90.00     .33     .040    -.052     .044      3.10     43.52
     0.00     0.00      .44    90.00    90.00     .54     .016    -.068     .041      4.26     47.16

    PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT

    TRAPPING LEVEL=   1.73 METERS BELOW SURFACE,  DILUTION=  29.52
1
  UNIVERSAL DATA FILE: stratver2.dat

  #9 Simulation of Wong's Stratified Flow data, Run 1020-82
```

```
 0.0000481          1  .01060  90.         2.
       0.       90.        1000.
        2    1.0000         0.
     00.00 0.99659      0.0
   10.0   1.03659      0.0
1
                                       PROGRAM UDKHDEN
                          SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
                          AMBIENT CURRENTS AND VERTICAL GRADIENTS.   AUG 1985

   UNIVERSAL DATA FILE: stratver2.dat
   CASE I.D.  #9 Simulation of Wong's Stratified Flow data, Run 1020-82

        SINGLE PORT DISCHARGE CASE
   DISCHARGE= 0.0000 CU-M/S  DENSITY=1.00000 G/CM3  ** DIAMETER=  .0106-M
   ** NUMBER OF PORTS=   1  ** SPACING=1000.00-M  ** DEPTH=   2.00-M
0          AMBIENT STRATIFICATION PROFILE
    DEPTH (M)    DENSITY (G/CM3)   VELOCITY (M/S)
        .00          .99659           .000
      10.00         1.03659           .000
0  FROUDE NO= 24.96,  PORT SPACING/PORT DIA=  94339.62,
+                                                      STARTING LENGTH=     .060

   ALL LENGTHS ARE IN METERS-TIME IN SEC.  FIRST LINE ARE INITIAL CONDITIONS.
     X       Y       Z      TH1     TH2     WIDTH     DUCL     DRHO     DCCL       TIME   DILUTION

     .00     .00     .00   90.00   90.00     .01    1.000    1.000    1.000       .00     1.00
    0.00    0.00     .06   90.00   90.00     .03    1.000     .914     .967       .11     1.95
    0.00    0.00     .15   90.00   90.00     .09     .317     .186     .295       .43     6.39

   PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

    0.00    0.00     .23   90.00   90.00     .16     .191    -.004     .172      1.08    10.93
    0.00    0.00     .32   90.00   90.00     .23     .125    -.124     .122      2.09    15.43
    0.00    0.00     .40   90.00   90.00     .41     .051    -.228     .097      3.88    19.39

   PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT

   TRAPPING LEVEL=   1.77 METERS BELOW SURFACE,  DILUTION=  10.81
 #10 Simulation of Wong's Stratified Flow data, Run 1028-82
 0 1 0 0 0 0 0
 0.0000395          1  .01060  90.         2.
       0.       90.        1000.
        2    1.0000         0.
     00.00 0.9870       0.0
   10.0   1.07967      0.0
1
                                       PROGRAM UDKHDEN
                          SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
                          AMBIENT CURRENTS AND VERTICAL GRADIENTS.   AUG 1985

   UNIVERSAL DATA FILE: stratver3.dat
   CASE I.D.  #10 Simulation of Wong's Stratified Flow data, Run 1028-82

        SINGLE PORT DISCHARGE CASE
   DISCHARGE= 0.0000 CU-M/S  DENSITY=1.00000 G/CM3  ** DIAMETER=  .0106-M
```

```
0         AMBIENT STRATIFICATION PROFILE
     DEPTH (M)    DENSITY (G/CM3)   VELOCITY (M/S)
          .00          .98700           .000
        10.00         1.07967           .000
0   FROUDE NO= 18.67,  PORT SPACING/PORT DIA=  94339.62,
+                                                      STARTING LENGTH=     .060

    ALL LENGTHS ARE IN METERS-TIME IN SEC.  FIRST LINE ARE INITIAL CONDITIONS.
      X        Y        Z       TH1      TH2     WIDTH      DUCL      DRHO      DCCL       TIME    DILUTION

     .00      .00      .00    90.00    90.00       .01     1.000     1.000     1.000        .00      1.00
    0.00     0.00      .06    90.00    90.00       .03     1.000      .839      .937        .14      1.97
    0.00     0.00      .15    90.00    90.00       .09      .320      .078      .286        .52      6.45

    PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

    0.00     0.00      .23    90.00    90.00       .16      .176     -.172      .168       1.33     10.96
    0.00     0.00      .30    90.00    90.00       .38      .043     -.344      .129       2.88     14.32

    PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT

    TRAPPING LEVEL=   1.83 METERS BELOW SURFACE,  DILUTION=   7.64
1
  UNIVERSAL DATA FILE: stratver3.dat

    CASE I.D.  #11 Simulation of Wong's Stratified Flow data,Run 0929-82

          SINGLE PORT DISCHARGE CASE
    DISCHARGE= 0.0000 CU-M/S  DENSITY=1.00000 G/CM3  ** DIAMETER=  .0051-M
    ** NUMBER OF PORTS=   1  ** SPACING=1000.00-M  ** DEPTH=   2.00-M
0         AMBIENT STRATIFICATION PROFILE
     DEPTH (M)    DENSITY (G/CM3)   VELOCITY (M/S)
          .00          .98322           .000
        10.00         1.08662           .000
0   FROUDE NO=172.71,  PORT SPACING/PORT DIA= 195694.72,
+                                                      STARTING LENGTH=     .029

    ALL LENGTHS ARE IN METERS-TIME IN SEC.  FIRST LINE ARE INITIAL CONDITIONS.
      X        Y        Z       TH1      TH2     WIDTH      DUCL      DRHO      DCCL       TIME    DILUTION

     .00      .00      .00    90.00    90.00       .01     1.000     1.000     1.000        .00      1.00
    0.00     0.00      .03    90.00    90.00       .01     1.000      .891      .968        .01      1.93
    0.00     0.00      .07    90.00    90.00       .05      .306      .136      .296        .05      6.31

    PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

    0.00     0.00      .11    90.00    90.00       .08      .180     -.086      .174        .12     10.69
    0.00     0.00      .15    90.00    90.00       .11      .127     -.239      .124        .24     15.06
    0.00     0.00      .19    90.00    90.00       .14      .098     -.371      .096        .39     19.42
    0.00     0.00      .23    90.00    90.00       .18      .077     -.493      .079        .58     23.74
    0.00     0.00      .27    90.00    90.00       .21      .062     -.612      .067        .83     27.96
    0.00     0.00      .32    90.00    90.00       .26      .048     -.730      .058       1.14     32.00
    0.00     0.00      .36    90.00    90.00       .33      .033     -.853      .052       1.56     35.71
    0.00     0.00      .40    90.00    90.00       .69      .008     -.990      .048       2.37     38.61

    PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT
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     TRAPPING LEVEL=   1.91 METERS BELOW SURFACE,  DILUTION=   8.71
   UNIVERSAL DATA FILE: stratver3.dat

   #12 Simulation of Wong's Stratified Flow data, Run 1001-82
   0 1 0 0 0 0 0
  0.0000585          1  .00511  90.         2.
          0.       90.       1000.
           2    1.0000        0.
       00.00 0.9917    0.0
     10.0   1.05970     0.
1
                                             PROGRAM UDKHDEN
                              SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
                              AMBIENT CURRENTS AND VERTICAL GRADIENTS.   AUG 1985

     UNIVERSAL DATA FILE: stratver3.dat
     CASE I.D.  #12 Simulation of Wong's Stratified Flow data, Run 1001-82

           SINGLE PORT DISCHARGE CASE
     DISCHARGE=  .0001 CU-M/S  DENSITY=1.00000 G/CM3  ** DIAMETER=  .0051-M
     ** NUMBER OF PORTS=   1  ** SPACING=1000.00-M  ** DEPTH=   2.00-M
0          AMBIENT STRATIFICATION PROFILE
      DEPTH (M)    DENSITY (G/CM3)   VELOCITY (M/S)
          .00          .99170            .000
        10.00        1.05970             .000
0    FROUDE NO=175.09,  PORT SPACING/PORT DIA= 195694.72,
+                                                                STARTING LENGTH=     .029

     ALL LENGTHS ARE IN METERS-TIME IN SEC.  FIRST LINE ARE INITIAL CONDITIONS.
       X       Y       Z      TH1      TH2     WIDTH     DUCL     DRHO     DCCL      TIME   DILUTION

      .00     .00     .00   90.00    90.00      .01     1.000    1.000    1.000       .00      1.00
     0.00    0.00     .03   90.00    90.00      .01     1.000     .947     .985       .01      1.93
     0.00    0.00     .07   90.00    90.00      .05      .306     .223     .301       .04      6.31
     0.00    0.00     .11   90.00    90.00      .08      .181     .051     .178       .10     10.69

     PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

     0.00    0.00     .15   90.00    90.00      .11      .128    -.050     .126       .20     15.07
     0.00    0.00     .19   90.00    90.00      .14      .099    -.128     .098       .33     19.45
     0.00    0.00     .23   90.00    90.00      .17      .080    -.197     .080       .49     23.82
     0.00    0.00     .27   90.00    90.00      .21      .066    -.260     .067       .69     28.15
     0.00    0.00     .32   90.00    90.00      .24      .055    -.320     .059       .92     32.41
     0.00    0.00     .36   90.00    90.00      .29      .046    -.379     .052      1.21     36.56
     0.00    0.00     .40   90.00    90.00      .34      .036    -.438     .047      1.56     40.52
     0.00    0.00     .44   90.00    90.00      .42      .026    -.499     .043      2.02     44.15
     0.00    0.00     .48   90.00    90.00      .71      .009    -.566     .040      2.84     47.06

     PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT

     TRAPPING LEVEL=   1.87 METERS BELOW SURFACE,  DILUTION=  12.73
1
  UNIVERSAL DATA FILE: stratver3.dat

  #13 Simulation of Wong's Stratified Flow data, Run 1006-82
  0 1 0 0 0 0 0
```

```
         0.       90.       1000.
          2    1.0000         0.
      00.00 0.98816    0.0
    10.0  1.06586     0.0
1
                                          PROGRAM UDKHDEN
                         SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
                         AMBIENT CURRENTS AND VERTICAL GRADIENTS.   AUG 1985

    UNIVERSAL DATA FILE: stratver3.dat
    CASE I.D.  #13 Simulation of Wong's Stratified Flow data, Run 1006-82

          SINGLE PORT DISCHARGE CASE
    DISCHARGE= 0.0000 CU-M/S  DENSITY=1.00000 G/CM3  ** DIAMETER=  .0051-M
    ** NUMBER OF PORTS=   1  ** SPACING=1000.00-M  ** DEPTH=   2.00-M
0          AMBIENT STRATIFICATION PROFILE
     DEPTH (M)    DENSITY (G/CM3)   VELOCITY (M/S)
          .00         .98816            .000
        10.00        1.06586            .000
0   FROUDE NO=111.40,  PORT SPACING/PORT DIA= 195694.72,
+                                                         STARTING LENGTH=     .029

    ALL LENGTHS ARE IN METERS-TIME IN SEC.  FIRST LINE ARE INITIAL CONDITIONS.
      X       Y       Z     TH1      TH2    WIDTH     DUCL     DRHO     DCCL       TIME  DILUTION

      .00     .00     .00   90.00   90.00      .01    1.000   1.000    1.000        .00     1.00
     0.00    0.00     .03   90.00   90.00      .01    1.000    .913     .975        .02     1.93
     0.00    0.00     .07   90.00   90.00      .05     .306    .171     .298        .08     6.31

    PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

     0.00    0.00     .11   90.00   90.00      .08     .181   -.031     .176        .19    10.70
     0.00    0.00     .15   90.00   90.00      .11     .127   -.163     .125        .37    15.08
     0.00    0.00     .19   90.00   90.00      .14     .097   -.273     .097        .62    19.43
     0.00    0.00     .23   90.00   90.00      .18     .075   -.375     .079        .94    23.70
     0.00    0.00     .27   90.00   90.00      .22     .056   -.473     .068       1.35    27.79
     0.00    0.00     .32   90.00   90.00      .30     .036   -.573     .060       1.94    31.49

    PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT

    TRAPPING LEVEL=   1.90 METERS BELOW SURFACE,  DILUTION=   9.86
1
  UNIVERSAL DATA FILE: stratver3.dat

  #14 Simulation of Wong's Stratified Flow data, Run 1014-82
  0 1 0 0 0 0 0
 0.0000211          1  .00511  90.         2.
         0.       90.       1000.
          2    1.0000         0.
      00.00 0.99238    0.0
    10.0  1.05798     0.0
1
                                          PROGRAM UDKHDEN
                         SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
                         AMBIENT CURRENTS AND VERTICAL GRADIENTS.   AUG 1985
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   CASE I.D.  #14 Simulation of Wong's Stratified Flow data, Run 1014-82

         SINGLE PORT DISCHARGE CASE
   DISCHARGE= 0.0000 CU-M/S  DENSITY=1.00000 G/CM3  ** DIAMETER=  .0051-M
   ** NUMBER OF PORTS=   1  ** SPACING=1000.00-M  ** DEPTH=   2.00-M
0          AMBIENT STRATIFICATION PROFILE
    DEPTH (M)    DENSITY (G/CM3)   VELOCITY (M/S)
         .00          .99238            .000
       10.00         1.05798            .000
0  FROUDE NO= 61.99,  PORT SPACING/PORT DIA= 195694.72,
+                                                      STARTING LENGTH=     .029

   ALL LENGTHS ARE IN METERS-TIME IN SEC.  FIRST LINE ARE INITIAL CONDITIONS.
     X       Y       Z      TH1     TH2     WIDTH    DUCL     DRHO     DCCL      TIME   DILUTION

     .00     .00     .00   90.00   90.00     .01    1.000    1.000    1.000       .00     1.00
    0.00    0.00     .03   90.00   90.00     .01    1.000     .949     .984       .03     1.93
    0.00    0.00     .07   90.00   90.00     .05     .308     .229     .301       .11     6.32
    0.00    0.00     .11   90.00   90.00     .08     .183     .060     .177       .28    10.73

   PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

    0.00    0.00     .15   90.00   90.00     .11     .130    -.038     .125       .55    15.15
    0.00    0.00     .19   90.00   90.00     .14     .098    -.113     .097       .90    19.55
    0.00    0.00     .23   90.00   90.00     .18     .074    -.178     .080      1.37    23.84
    0.00    0.00     .27   90.00   90.00     .24     .050    -.240     .068      2.01    27.84
    0.00    0.00     .32   90.00   90.00     .63     .008    -.305     .061      3.38    30.95

   PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT

   TRAPPING LEVEL=   1.87 METERS BELOW SURFACE,  DILUTION=  13.27
1
  UNIVERSAL DATA FILE: stratver3.dat

  #15 Simulation of Wong's Stratified Flow data, Run 1019-82
  0 1 0 0 0 0 0
 0.0000634          1  .00511  90.         2.
        0.       90.       1000.
         2    1.0000         0.
     00.00  0.97503    0.0
     00.00  0.97503    0.0
1
                                 PROGRAM UDKHDEN
                      SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
                      AMBIENT CURRENTS AND VERTICAL GRADIENTS.   AUG 1985

   UNIVERSAL DATA FILE: stratver3.dat
   CASE I.D.  #15 Simulation of Wong's Stratified Flow data, Run 1019-82

         SINGLE PORT DISCHARGE CASE
   DISCHARGE=  .0001 CU-M/S  DENSITY=1.00000 G/CM3  ** DIAMETER=  .0051-M
   ** NUMBER OF PORTS=   1  ** SPACING=1000.00-M  ** DEPTH=   2.00-M
0          AMBIENT STRATIFICATION PROFILE
    DEPTH (M)    DENSITY (G/CM3)   VELOCITY (M/S)
         .00          .97503            .000
```

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+                                                                   STARTING LENGTH=     .029

    ALL LENGTHS ARE IN METERS-TIME IN SEC.  FIRST LINE ARE INITIAL CONDITIONS.
      X        Y        Z       TH1      TH2     WIDTH      DUCL      DRHO      DCCL       TIME   DILUTION

     .00      .00      .00    90.00    90.00      .01     1.000     1.000     1.000        .00      1.00
    0.00     0.00      .03    90.00    90.00      .01     1.000      .973      .986        .01      1.94
    0.00     0.00      .07    90.00    90.00      .05      .316      .274      .301        .04      6.37
    0.00     0.00      .11    90.00    90.00      .08      .195      .132      .176        .09     10.91
    0.00     0.00      .15    90.00    90.00      .10      .145      .063      .123        .17     15.59
    0.00     0.00      .19    90.00    90.00      .13      .115      .017      .094        .27     20.38

    PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

    0.00     0.00      .23    90.00    90.00      .17      .093     -.017      .076        .40     25.23
    0.00     0.00      .27    90.00    90.00      .21      .071     -.047      .064        .56     29.98
    0.00     0.00      .32    90.00    90.00      .28      .045     -.074      .056        .79     34.31

    PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT

    TRAPPING LEVEL=   1.79 METERS BELOW SURFACE,  DILUTION=  22.68
```

```
1
  UNIVERSAL DATA FILE: stratver5.dat

  #16 Simulation of Wong's Stratified Flow data, Run 0124-84
  0 1 0 0 0 0 0
 0.0000148          1  .00221  90.         2.
        0.       90.       1000.
         2    1.0000        0.
     00.00 0.97458      0.0
    10.0   1.11429     0.0
1
                                         PROGRAM UDKHDEN
                         SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
                         AMBIENT CURRENTS AND VERTICAL GRADIENTS.   AUG 1985

    UNIVERSAL DATA FILE: stratver5.dat
    CASE I.D.  #16 Simulation of Wong's Stratified Flow data, Run 0124-84

         SINGLE PORT DISCHARGE CASE
    DISCHARGE= 0.0000 CU-M/S  DENSITY=1.00000 G/CM3  ** DIAMETER=  .0022-M
    ** NUMBER OF PORTS=   1  ** SPACING=1000.00-M  ** DEPTH=   2.00-M
0          AMBIENT STRATIFICATION PROFILE
     DEPTH (M)    DENSITY (G/CM3)   VELOCITY (M/S)
         .00          .97458            .000
       10.00         1.11429            .000
0   FROUDE NO=522.04,  PORT SPACING/PORT DIA= 452488.69,
+                                                      STARTING LENGTH=     .013

    ALL LENGTHS ARE IN METERS-TIME IN SEC.  FIRST LINE ARE INITIAL CONDITIONS.
      X        Y        Z      TH1      TH2     WIDTH     DUCL     DRHO     DCCL      TIME   DILUTION

     .00      .00      .00   90.00    90.00     0.00    1.000    1.000    1.000       .00     1.00
    0.00     0.00      .01   90.00    90.00      .01    1.000     .902     .972      0.00     1.93
    0.00     0.00      .03   90.00    90.00      .02     .305     .152     .297       .01     6.30

    PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

    0.00     0.00      .05   90.00    90.00      .03     .180    -.060     .175       .03    10.68
    0.00     0.00      .07   90.00    90.00      .05     .128    -.204     .124       .06    15.06
    0.00     0.00      .08   90.00    90.00      .06     .099    -.325     .096       .10    19.44
    0.00     0.00      .10   90.00    90.00      .07     .081    -.437     .079       .16    23.81
    0.00     0.00      .12   90.00    90.00      .09     .068    -.543     .066       .22    28.18
    0.00     0.00      .14   90.00    90.00      .10     .058    -.647     .058       .29    32.53
    0.00     0.00      .15   90.00    90.00      .12     .051    -.748     .051       .38    36.85
    0.00     0.00      .17   90.00    90.00      .13     .044    -.849     .045       .47    41.14
    0.00     0.00      .19   90.00    90.00      .15     .039    -.950     .041       .58    45.38
    0.00     0.00      .21   90.00    90.00      .17     .034   -1.051     .038       .71    49.54
    0.00     0.00      .22   90.00    90.00      .18     .030   -1.153     .035       .85    53.60
    0.00     0.00      .24   90.00    90.00      .21     .025   -1.256     .033      1.02    57.51
    0.00     0.00      .26   90.00    90.00      .24     .021   -1.363     .031      1.21    61.21
    0.00     0.00      .28   90.00    90.00      .28     .015   -1.476     .029      1.47    64.58
    0.00     0.00      .30   90.00    90.00      .43     .007   -1.601     .028      1.88    67.34

    PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT

    TRAPPING LEVEL=    1.96 METERS BELOW SURFACE    DILUTION=    9.20
```

```
 UNIVERSAL DATA FILE: stratver5.dat

 #17 Simulation of Wong's Stratified Flow data,Run 0202-84
 0 1 0 0 0 0 0
0.0000193         1  .00221  90.         2.
        0.       90.       1000.
         2    1.0000        0.
     00.00 0.97381    0.0
   10.0   1.11862     0.0
1
                                          PROGRAM UDKHDEN
                        SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
                        AMBIENT CURRENTS AND VERTICAL GRADIENTS.   AUG 1985

   UNIVERSAL DATA FILE: stratver5.dat
   CASE I.D.  #17 Simulation of Wong's Stratified Flow data,Run 0202-84

         SINGLE PORT DISCHARGE CASE
   DISCHARGE= 0.0000 CU-M/S  DENSITY=1.00000 G/CM3  ** DIAMETER=  .0022-M
   ** NUMBER OF PORTS=   1  ** SPACING=1000.00-M  ** DEPTH=   2.00-M
0         AMBIENT STRATIFICATION PROFILE
    DEPTH (M)    DENSITY (G/CM3)   VELOCITY (M/S)
        .00          .97381            .000
      10.00         1.11862            .000
0  FROUDE NO=649.35,  PORT SPACING/PORT DIA= 452488.69,
+                                                          STARTING LENGTH=     .013

   ALL LENGTHS ARE IN METERS-TIME IN SEC.  FIRST LINE ARE INITIAL CONDITIONS.
     X       Y       Z      TH1      TH2     WIDTH     DUCL     DRHO     DCCL      TIME   DILUTION

    .00     .00     .00   90.00    90.00     0.00    1.000    1.000    1.000       .00      1.00
   0.00    0.00     .01   90.00    90.00      .01    1.000     .907     .973      0.00      1.93
   0.00    0.00     .03   90.00    90.00      .02     .305     .161     .297       .01      6.30

   PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

   0.00    0.00     .05   90.00    90.00      .03     .180    -.046     .175       .03     10.68
   0.00    0.00     .07   90.00    90.00      .05     .128    -.185     .124       .05     15.06
   0.00    0.00     .08   90.00    90.00      .06     .099    -.301     .096       .08     19.44
   0.00    0.00     .10   90.00    90.00      .07     .081    -.407     .079       .12     23.82
   0.00    0.00     .12   90.00    90.00      .09     .068    -.508     .066       .17     28.19
   0.00    0.00     .14   90.00    90.00      .10     .059    -.606     .058       .22     32.55
   0.00    0.00     .15   90.00    90.00      .12     .051    -.702     .051       .29     36.89
   0.00    0.00     .17   90.00    90.00      .13     .045    -.797     .045       .36     41.22
   0.00    0.00     .19   90.00    90.00      .15     .040    -.891     .041       .44     45.51
   0.00    0.00     .21   90.00    90.00      .16     .036    -.985     .038       .53     49.77
   0.00    0.00     .22   90.00    90.00      .18     .032   -1.080     .035       .64     53.96
   0.00    0.00     .24   90.00    90.00      .20     .029   -1.175     .032       .75     58.07
   0.00    0.00     .26   90.00    90.00      .22     .025   -1.271     .030       .89     62.08
   0.00    0.00     .28   90.00    90.00      .24     .022   -1.370     .028      1.04     65.93
   0.00    0.00     .30   90.00    90.00      .27     .018   -1.471     .027      1.21     69.59
   0.00    0.00     .31   90.00    90.00      .32     .014   -1.577     .026      1.44     72.94
   0.00    0.00     .33   90.00    90.00      .44     .008   -1.693     .025      1.77     75.77

   PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT
```

```
1
  UNIVERSAL DATA FILE: stratver5.dat

  #18 Simulation of Wong's Stratified Flow data, Run 0203-84
   0 1 0 0 0 0 0
 0.0000067          1  .00221  90.         2.
        0.       90.       1000.
         2    1.0000       0.
     00.00 0.99107    0.0
    10.0   1.03981    0.
1
                                 PROGRAM UDKHDEN
                    SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
                    AMBIENT CURRENTS AND VERTICAL GRADIENTS.   AUG 1985

    UNIVERSAL DATA FILE: stratver5.dat
    CASE I.D.  #18 Simulation of Wong's Stratified Flow data, Run 0203-84

          SINGLE PORT DISCHARGE CASE
    DISCHARGE= 0.0000 CU-M/S  DENSITY=1.00000 G/CM3  ** DIAMETER=  .0022-M
    ** NUMBER OF PORTS=   1  ** SPACING=1000.00-M  ** DEPTH=   2.00-M
0          AMBIENT STRATIFICATION PROFILE
     DEPTH (M)    DENSITY (G/CM3)   VELOCITY (M/S)
          .00          .99107            .000
        10.00         1.03981            .000
0   FROUDE NO=414.97,  PORT SPACING/PORT DIA= 452488.69,
+                                                          STARTING LENGTH=     .013

    ALL LENGTHS ARE IN METERS-TIME IN SEC.  FIRST LINE ARE INITIAL CONDITIONS.
      X       Y       Z      TH1      TH2      WIDTH     DUCL      DRHO      DCCL       TIME   DILUTION

     .00     .00     .00   90.00    90.00     0.00    1.000     1.000     1.000       .00     1.00
    0.00    0.00     .01   90.00    90.00      .01    1.000      .894      .969       .01     1.93
    0.00    0.00     .03   90.00    90.00      .02     .306      .141      .296       .03     6.30

    PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

    0.00    0.00     .05   90.00    90.00      .03     .180     -.078      .175       .07    10.68
    0.00    0.00     .07   90.00    90.00      .05     .128     -.229      .124       .14    15.06
    0.00    0.00     .08   90.00    90.00      .06     .099     -.357      .096       .23    19.44
    0.00    0.00     .10   90.00    90.00      .08     .080     -.476      .078       .35    23.81
    0.00    0.00     .12   90.00    90.00      .09     .067     -.590      .066       .48    28.16
    0.00    0.00     .14   90.00    90.00      .10     .057     -.701      .057       .65    32.49
    0.00    0.00     .15   90.00    90.00      .12     .050     -.810      .051       .84    36.77
    0.00    0.00     .17   90.00    90.00      .13     .043     -.919      .046      1.06    41.00
    0.00    0.00     .19   90.00    90.00      .15     .037    -1.029      .041      1.31    45.12
    0.00    0.00     .21   90.00    90.00      .17     .031    -1.140      .038      1.61    49.11
    0.00    0.00     .22   90.00    90.00      .20     .025    -1.254      .035      1.97    52.89
    0.00    0.00     .24   90.00    90.00      .24     .018    -1.374      .033      2.44    56.33
    0.00    0.00     .26   90.00    90.00      .38     .008    -1.508      .032      3.22    59.12

    PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT

    TRAPPING LEVEL=   1.96 METERS BELOW SURFACE,  DILUTION=   8.85
```

APPENDIX 1

LISTING OF UDKHDEN COMPUTER OUTPUTS

C. HORIZONTAL JETS IN STRATIFIED AMBIENT FLUIDS

```
1
  UNIVERSAL DATA FILE: STRATHOR1.DAT

  #1 Simulation of Wong's Stratified Flow data, Run 0519-83
  0 1 0 0 0 0 0
 0.0000277          1  .01480   0.         2.
       0.       90.       1000.
        2    1.0000        0.
     00.00 0.99032    0.0
   10.0   1.07812     0.
1
                                    PROGRAM UDKHDEN
                       SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
                       AMBIENT CURRENTS AND VERTICAL GRADIENTS.   AUG 1985

   UNIVERSAL DATA FILE: STRATHOR1.DAT
   CASE I.D.  #1 Simulation of Wong's Stratified Flow data, Run 0519-83

       SINGLE PORT DISCHARGE CASE
   DISCHARGE= 0.0000 CU-M/S  DENSITY=1.00000 G/CM3  ** DIAMETER=  .0148-M
   ** NUMBER OF PORTS=   1  ** SPACING=1000.00-M  ** DEPTH=   2.00-M
0          AMBIENT STRATIFICATION PROFILE
    DEPTH (M)    DENSITY (G/CM3)   VELOCITY (M/S)
        .00         .99032            .000
      10.00        1.07812            .000
0  FROUDE NO=  4.76,  PORT SPACING/PORT DIA=  67567.57,
+                                                         STARTING LENGTH=     .082

   ALL LENGTHS ARE IN METERS-TIME IN SEC.  FIRST LINE ARE INITIAL CONDITIONS.
     X       Y       Z      TH1     TH2     WIDTH     DUCL     DRHO     DCCL      TIME   DILUTION

     .00     .00     .00   90.00     .00      .01    1.000    1.000    1.000       .00     1.00
    0.00     .08     .01   90.00   19.13      .04    1.000     .924     .938       .52     2.04
    0.00     .18     .08   90.00   52.81      .12     .452     .164     .272      1.77     7.03

   PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

    0.00     .24     .18   90.00   54.73      .21     .257    -.075     .147      3.84    12.96
    0.00     .30     .21   90.00  -40.07      .30     .155    -.104     .119      6.61    16.08

   PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT

   TRAPPING LEVEL=   1.86 METERS BELOW SURFACE,  DILUTION=  10.68
1
  UNIVERSAL DATA FILE: STRATHOR1.DAT

  #2 Simulation of Wong's Stratified Flow data,Run 0916-83
  0 1 0 0 0 0 0
 0.0000272          1  .01060   0.         2.
       0.       90.       1000.
        2    1.0000        0.
     00.00 1.00048    0.0
   10.00  1.06758    0.0
1
                                    PROGRAM UDKHDEN
                       SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
```

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    UNIVERSAL DATA FILE: STRATHOR1.DAT
    CASE I.D.  #2 Simulation of Wong's Stratified Flow data,Run 0916-83

          SINGLE PORT DISCHARGE CASE
    DISCHARGE= 0.0000 CU-M/S  DENSITY=1.00000 G/CM3  ** DIAMETER=  .0106-M
    ** NUMBER OF PORTS=   1  ** SPACING=1000.00-M  ** DEPTH=   2.00-M
0          AMBIENT STRATIFICATION PROFILE
     DEPTH (M)    DENSITY (G/CM3)   VELOCITY (M/S)
         .00        1.00048           .000
       10.00        1.06758           .000
0   FROUDE NO=  8.11,  PORT SPACING/PORT DIA=  94339.62,
+                                                     STARTING LENGTH=     .061

    ALL LENGTHS ARE IN METERS-TIME IN SEC.  FIRST LINE ARE INITIAL CONDITIONS.
      X        Y        Z       TH1      TH2     WIDTH     DUCL     DRHO     DCCL       TIME    DILUTION

      .00      .00      .00    90.00      .00      .01    1.000    1.000    1.000        .00      1.00
     0.00      .06     0.00    90.00     6.93      .03    1.000     .990     .992        .20      1.94
     0.00      .14      .03    90.00    30.48      .09     .346     .281     .299        .75      6.44
     0.00      .20      .09    90.00    51.41      .14     .266     .115     .167       1.67     11.55
     0.00      .25      .16    90.00    59.59      .19     .217     .022     .110       2.81     17.43

    PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

     0.00      .29      .23    90.00    55.98      .27     .146    -.043     .082       4.32     23.53
     0.00      .35      .26    90.00   -23.39      .41     .073    -.068     .069       6.82     27.94

    PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT

    TRAPPING LEVEL=   1.82 METERS BELOW SURFACE,  DILUTION=  19.32
1
  UNIVERSAL DATA FILE: STRATHOR1.DAT

  #3 Simulation of Wong's Stratified Flow data, Run 0920-83
  0 1 0 0 0 0 0
 0.0000200         1  .01060   0.        2.
       0.       90.       1000.
         2    1.0000       0.
     00.00 0.99579    0.0
    10.0   1.08349    0.0
1
                              PROGRAM UDKHDEN
                        SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
                        AMBIENT CURRENTS AND VERTICAL GRADIENTS.   AUG 1985

    UNIVERSAL DATA FILE: STRATHOR1.DAT
    CASE I.D.  #3 Simulation of Wong's Stratified Flow data, Run 0920-83

          SINGLE PORT DISCHARGE CASE
    DISCHARGE= 0.0000 CU-M/S  DENSITY=1.00000 G/CM3  ** DIAMETER=  .0106-M
    ** NUMBER OF PORTS=   1  ** SPACING=1000.00-M  ** DEPTH=   2.00-M
0          AMBIENT STRATIFICATION PROFILE
     DEPTH (M)    DENSITY (G/CM3)   VELOCITY (M/S)
         .00         .99579           .000
       10.00        1.08349           .000
```

```
+                                                                 STARTING LENGTH=     .061

    ALL LENGTHS ARE IN METERS-TIME IN SEC.  FIRST LINE ARE INITIAL CONDITIONS.
      X       Y       Z      TH1      TH2     WIDTH     DUCL     DRHO     DCCL      TIME   DILUTION

     .00     .00     .00   90.00      .00      .01    1.000    1.000    1.000       .00      1.00
    0.00     .06     .01   90.00    12.13      .03    1.000     .972     .976       .27      1.97
    0.00     .13     .04   90.00    43.86      .09     .400     .252     .288       .96      6.67
    0.00     .18     .11   90.00    60.58      .13     .315     .069     .155      2.02     12.39

    PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

    0.00     .22     .19   90.00    61.90      .20     .216    -.033     .102      3.43     18.82
    0.00     .27     .23   90.00   -18.70      .36     .081    -.081     .081      5.90     23.63

    PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT

    TRAPPING LEVEL=   1.84 METERS BELOW SURFACE,  DILUTION=  16.43
1
  UNIVERSAL DATA FILE: STRATHOR1.DAT

  #4 Simulation of Wong's Stratified Flow data, Run 1003-83
  0 1 0 0 0 0 0
 0.0000341         1  .01060   0.         2.
       0.       90.       1000.
        2    1.0000        0.
     00.00 1.01177    0.0
   10.0   1.08173     0.0
1
                                  PROGRAM UDKHDEN
                       SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
                       AMBIENT CURRENTS AND VERTICAL GRADIENTS.   AUG 1985

    UNIVERSAL DATA FILE: STRATHOR1.DAT
    CASE I.D.  #4 Simulation of Wong's Stratified Flow data, Run 1003-83

          SINGLE PORT DISCHARGE CASE
    DISCHARGE= 0.0000 CU-M/S  DENSITY=1.00000 G/CM3  ** DIAMETER=  .0106-M
    ** NUMBER OF PORTS=   1  ** SPACING=1000.00-M  ** DEPTH=   2.00-M
0         AMBIENT STRATIFICATION PROFILE
     DEPTH (M)    DENSITY (G/CM3)   VELOCITY (M/S)
          .00         1.01177             .000
        10.00         1.08173             .000
0   FROUDE NO=  7.47,  PORT SPACING/PORT DIA=  94339.62,
+                                                                 STARTING LENGTH=     .061

    ALL LENGTHS ARE IN METERS-TIME IN SEC.  FIRST LINE ARE INITIAL CONDITIONS.
      X       Y       Z      TH1      TH2     WIDTH     DUCL     DRHO     DCCL      TIME   DILUTION

     .00     .00     .00   90.00      .00      .01    1.000    1.000    1.000       .00      1.00
    0.00     .06    0.00   90.00     8.16      .03    1.000     .988     .989       .16      1.95
    0.00     .14     .03   90.00    34.58      .09     .360     .285     .297       .59      6.49
    0.00     .20     .09   90.00    55.96      .13     .290     .132     .163      1.28     11.80
    0.00     .24     .17   90.00    65.28      .18     .252     .054     .106      2.09     18.12
    0.00     .27     .25   90.00    68.35      .23     .206     .004     .077      3.05     25.13
```

```
     0.00     .30     .32   90.00   64.37      .32     .137    -.034     .060      4.32    32.16
     0.00     .35     .36   90.00  -35.15      .54     .055    -.052     .052      6.66    37.04

    PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT

    TRAPPING LEVEL=   1.75 METERS BELOW SURFACE,  DILUTION=  25.78
1
  UNIVERSAL DATA FILE: STRATHOR1.DAT

  #5 Simulation of Wong's Stratified Flow data,Run 0919-83
  0 1 0 0 0 0 0
 0.0000386          1  .01060   0.         2.
        0.       90.       1000.
         2    1.0000        0.
      00.00 0.99239    0.0
     10.0   1.09080     0.0
1
                                    PROGRAM UDKHDEN
                         SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
                         AMBIENT CURRENTS AND VERTICAL GRADIENTS.   AUG 1985

    UNIVERSAL DATA FILE: STRATHOR1.DAT
    CASE I.D.  #5 Simulation of Wong's Stratified Flow data,Run 0919-83

         SINGLE PORT DISCHARGE CASE
    DISCHARGE= 0.0000 CU-M/S  DENSITY=1.00000 G/CM3  ** DIAMETER=  .0106-M
    ** NUMBER OF PORTS=   1  ** SPACING=1000.00-M  ** DEPTH=   2.00-M
0          AMBIENT STRATIFICATION PROFILE
     DEPTH (M)    DENSITY (G/CM3)   VELOCITY (M/S)
         .00          .99239           .000
       10.00         1.09080           .000
0   FROUDE NO= 12.35,  PORT SPACING/PORT DIA=  94339.62,
+                                                       STARTING LENGTH=     .061

    ALL LENGTHS ARE IN METERS-TIME IN SEC.  FIRST LINE ARE INITIAL CONDITIONS.
       X       Y       Z      TH1     TH2     WIDTH     DUCL     DRHO     DCCL      TIME   DILUTION

      .00     .00     .00   90.00     .00      .01    1.000    1.000    1.000       .00     1.00
     0.00     .06    0.00   90.00    3.01      .03    1.000     .997     .998       .14     1.93
     0.00     .15     .01   90.00   14.77      .09     .314     .290     .304       .54     6.33
     0.00     .22     .05   90.00   31.61      .15     .207     .126     .176      1.33    10.91
     0.00     .29     .10   90.00   40.90      .21     .161     .018     .122      2.39    15.82

    PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

     0.00     .36     .15   90.00   33.63      .29     .111    -.060     .093      3.82    20.80
     0.00     .44     .17   90.00  -20.89      .37     .081    -.068     .076      6.01    25.32

    PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT

    TRAPPING LEVEL=   1.89 METERS BELOW SURFACE,  DILUTION=  16.85
1
  UNIVERSAL DATA FILE: STRATHOR1.DAT

  #6 Simulation of Wong's Stratified Flow data, Run 1011-83B
```

```
 0.0000115          1  .01060   0.         2.
        0.       90.       1000.
         2    1.0000        0.
      00.00 0.99675    0.0
     10.0   1.09781     0.
1
                                    PROGRAM UDKHDEN
                        SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
                        AMBIENT CURRENTS AND VERTICAL GRADIENTS.   AUG 1985

    UNIVERSAL DATA FILE: STRATHOR1.DAT
    CASE I.D.  #6 Simulation of Wong's Stratified Flow data, Run 1011-83B

          SINGLE PORT DISCHARGE CASE
    DISCHARGE= 0.0000 CU-M/S  DENSITY=1.00000 G/CM3  ** DIAMETER=  .0106-M
    ** NUMBER OF PORTS=   1  ** SPACING=1000.00-M  ** DEPTH=   2.00-M
0          AMBIENT STRATIFICATION PROFILE
     DEPTH (M)    DENSITY (G/CM3)   VELOCITY (M/S)
         .00           .99675             .000
       10.00          1.09781             .000
0   FROUDE NO=  3.10,  PORT SPACING/PORT DIA=  94339.62,
+                                                          STARTING LENGTH=     .053

    ALL LENGTHS ARE IN METERS-TIME IN SEC.  FIRST LINE ARE INITIAL CONDITIONS.
       X       Y       Z      TH1      TH2     WIDTH     DUCL      DRHO      DCCL       TIME   DILUTION

      .00     .00     .00    90.00      .00      .01    1.000     1.000     1.000        .00     1.00
     0.00     .05     .02    90.00    38.45      .03    1.000      .770      .780        .44     2.46
     0.00     .10     .09    90.00    69.86      .08     .641      .167      .222       1.30     8.63
     0.00     .12     .17    90.00    76.27      .13     .471      .015      .113       2.48    16.94

    PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

     0.00     .15     .25    90.00    60.64      .27     .154     -.068      .076       4.53    25.32

    PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT

    TRAPPING LEVEL=   1.82 METERS BELOW SURFACE,  DILUTION=  18.35
1
  UNIVERSAL DATA FILE: STRATHOR1.DAT

  #7 Simulation of Wong's Stratified Flow data, Run 0922-83
  0 1 0 0 0 0 0
 0.0000222          1  .00511   0.         2.
        0.       90.       1000.
         2    1.0000        0.
      00.00 0.99766    0.0
      00.00 0.99766    0.0
1
                                    PROGRAM UDKHDEN
                        SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
                        AMBIENT CURRENTS AND VERTICAL GRADIENTS.   AUG 1985

    UNIVERSAL DATA FILE: STRATHOR1.DAT
    CASE I.D.  #7 Simulation of Wong's Stratified Flow data, Run 0922-83
```

```
    DISCHARGE= 0.0000 CU-M/S  DENSITY=1.00000 G/CM3  ** DIAMETER=  .0051-M
    ** NUMBER OF PORTS=   1  ** SPACING=1000.00-M  ** DEPTH=   2.00-M
0          AMBIENT STRATIFICATION PROFILE
     DEPTH (M)    DENSITY (G/CM3)   VELOCITY (M/S)
         .00          .99766            .000
       10.00          .00000            .000
0   FROUDE NO= 10.77,  PORT SPACING/PORT DIA= 195694.72,
+                                                           STARTING LENGTH=     .030

    ALL LENGTHS ARE IN METERS-TIME IN SEC.  FIRST LINE ARE INITIAL CONDITIONS.
      X        Y        Z       TH1      TH2      WIDTH      DUCL      DRHO      DCCL       TIME    DILUTION

     .00      .00      .00    90.00      .00       .01     1.000     1.000     1.000        .00      1.00
    0.00      .03     0.00    90.00     3.96       .01     1.000      .997      .997        .03      1.93
    0.00      .07      .01    90.00    19.20       .04      .321      .298      .303        .10      6.35
    0.00      .10      .03    90.00    39.92       .07      .226      .155      .174        .25     11.07
    0.00      .13      .06    90.00    53.48       .09      .196      .081      .117        .43     16.40
    0.00      .15      .09    90.00    60.11       .11      .172      .031      .086        .64     22.34

    PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

    0.00      .17      .13    90.00    61.70       .14      .141     -.006      .067        .88     28.64
    0.00      .19      .16    90.00    54.93       .19      .096     -.036      .055       1.19     34.78
    0.00      .23      .18    90.00   -24.37       .27      .054     -.046      .048       1.78     39.75

    PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT

    TRAPPING LEVEL=   1.88 METERS BELOW SURFACE,  DILUTION=  27.48

1
  UNIVERSAL DATA FILE: STRATHOR2.DAT

  #8 Simulation of Wong's Stratified Flow data, Run 0509-83
  0 1 0 0 0 0 0
 0.0000074          1  .00511   0.         2.
        0.       90.       1000.
         2    1.0000        0.
      00.00 0.99354    0.0
    10.0   1.02984     0.0
1
                                             PROGRAM UDKHDEN
                              SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
                              AMBIENT CURRENTS AND VERTICAL GRADIENTS.   AUG 1985

    UNIVERSAL DATA FILE: STRATHOR2.DAT
    CASE I.D.  #8 Simulation of Wong's Stratified Flow data, Run 0509-83

          SINGLE PORT DISCHARGE CASE
    DISCHARGE= 0.0000 CU-M/S  DENSITY=1.00000 G/CM3  ** DIAMETER=  .0051-M
    ** NUMBER OF PORTS=   1  ** SPACING=1000.00-M  ** DEPTH=   2.00-M
0          AMBIENT STRATIFICATION PROFILE
     DEPTH (M)    DENSITY (G/CM3)   VELOCITY (M/S)
         .00          .99354            .000
       10.00         1.02984            .000
0   FROUDE NO= 57.01,  PORT SPACING/PORT DIA= 195694.72,
+                                                           STARTING LENGTH=     .030
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    ALL LENGTHS ARE IN METERS-TIME IN SEC.  FIRST LINE ARE INITIAL CONDITIONS.
      X        Y         Z        TH1      TH2      WIDTH      DUCL       DRHO       DCCL       TIME    DILUTIO

      .00      .00      .00    90.00      .00       .01     1.000      1.000      1.000        .00      1.00
     0.00      .03     0.00    90.00      .14       .01     1.000      1.000      1.000        .08      1.93
     0.00      .07     0.00    90.00      .73       .05      .305       .304       .305        .32      6.30
     0.00      .11     0.00    90.00     1.91       .08      .180       .173       .180        .82     10.68
     0.00      .15     0.00    90.00     3.56       .11      .128       .108       .128       1.57     15.07
     0.00      .19      .01    90.00     5.33       .14      .099       .059       .099       2.58     19.45
     0.00      .23      .01    90.00     6.51       .17      .081       .014       .081       3.85     23.84

    PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

     0.00      .27      .02    90.00     6.12       .20      .069      -.026       .068       5.37     28.23
     0.00      .31      .02    90.00     3.38       .24      .059      -.051       .059       7.15     32.62
     0.00      .36      .02    90.00    -1.39       .27      .052      -.051       .052       9.20     37.00

    PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT

    TRAPPING LEVEL=   1.99 METERS BELOW SURFACE,  DILUTION=  25.28
1
  UNIVERSAL DATA FILE: STRATHOR2.DAT

  #9 Simulation of Wong's Stratified Flow data, Run 0511-83
  0 1 0 0 0 0 0
 0.0000120          1  .00511   0.         2.
       0.       90.       1000.
        2    1.0000       0.
     00.00 0.99522    0.0
     00.00 0.99522    0.0
1
                                    PROGRAM UDKHDEN
                      SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
                      AMBIENT CURRENTS AND VERTICAL GRADIENTS.   AUG 1985

    UNIVERSAL DATA FILE: STRATHOR2.DAT
    CASE I.D.  #9 Simulation of Wong's Stratified Flow data, Run 0511-83

        SINGLE PORT DISCHARGE CASE
    DISCHARGE= 0.0000 CU-M/S  DENSITY=1.00000 G/CM3  ** DIAMETER=  .0051-M
    ** NUMBER OF PORTS=   1  ** SPACING=1000.00-M  ** DEPTH=   2.00-M
0        AMBIENT STRATIFICATION PROFILE
     DEPTH (M)    DENSITY (G/CM3)   VELOCITY (M/S)
         .00          .99522            .000
       10.00          .00000            .000
0   FROUDE NO=  5.79,  PORT SPACING/PORT DIA= 195694.72,
+                                                       STARTING LENGTH=     .029

    ALL LENGTHS ARE IN METERS-TIME IN SEC.  FIRST LINE ARE INITIAL CONDITIONS.
      X        Y         Z        TH1      TH2      WIDTH      DUCL       DRHO       DCCL       TIME    DILUTIO

      .00      .00      .00    90.00      .00       .01     1.000      1.000      1.000        .00      1.00
     0.00      .03     0.00    90.00    13.37       .01     1.000       .971       .972        .05      1.98
     0.00      .06      .02    90.00    47.00       .04      .418       .272       .285        .18      6.74
     0.00      .09      .06    90.00    65.02       .06      .355       .119       .151        .36     12.75
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    PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

     0.00      .12      .17   90.00   70.42       .15      .157     -.031      .053       1.17    36.27
     0.00      .14      .19   90.00  -12.04       .29      .051     -.047      .047       1.69    40.54

    PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT

    TRAPPING LEVEL=   1.86 METERS BELOW SURFACE,  DILUTION=  28.55
1
  UNIVERSAL DATA FILE: STRATHOR4.DAT

  #10 Simulation of Wong's Stratified Flow data, Run 1010-83
  0 1 0 0 0 0 0
 0.0000258          1  .00221   0.         2.
        0.       90.       1000.
         2    1.0000        0.
      00.00 1.00278    0.0
    10.0   1.08171     0.0
1
                                   PROGRAM UDKHDEN
                         SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
                         AMBIENT CURRENTS AND VERTICAL GRADIENTS.   AUG 1985

    UNIVERSAL DATA FILE: STRATHOR4.DAT
    CASE I.D.  #10 Simulation of Wong's Stratified Flow data, Run 1010-83

          SINGLE PORT DISCHARGE CASE
    DISCHARGE= 0.0000 CU-M/S  DENSITY=1.00000 G/CM3  ** DIAMETER=  .0022-M
    ** NUMBER OF PORTS=   1  ** SPACING=1000.00-M  ** DEPTH=   2.00-M
0          AMBIENT STRATIFICATION PROFILE
     DEPTH (M)    DENSITY (G/CM3)   VELOCITY (M/S)
          .00        1.00278           .000
        10.00        1.08171           .000
0   FROUDE NO=335.41,  PORT SPACING/PORT DIA= 452488.69,
+                                                         STARTING LENGTH=     .013

    ALL LENGTHS ARE IN METERS-TIME IN SEC.  FIRST LINE ARE INITIAL CONDITIONS.
      X        Y        Z       TH1      TH2      WIDTH     DUCL      DRHO      DCCL       TIME   DILUTION

      .00      .00      .00   90.00      .00     0.00     1.000     1.000     1.000       .00      1.00
     0.00      .01     0.00   90.00     0.00      .01     1.000     1.000     1.000      0.00      1.93
     0.00      .03     0.00   90.00      .02      .02      .305      .305      .305       .01      6.30
     0.00      .05     0.00   90.00      .06      .03      .180      .180      .180       .02     10.68
     0.00      .07     0.00   90.00      .11      .05      .128      .128      .128       .04     15.06
     0.00      .08     0.00   90.00      .18      .06      .099      .099      .099       .06     19.44
     0.00      .10     0.00   90.00      .27      .07      .081      .081      .081       .09     23.82
     0.00      .12     0.00   90.00      .38      .09      .068      .068      .068       .13     28.20
     0.00      .14     0.00   90.00      .50      .10      .059      .059      .059       .17     32.58
     0.00      .15     0.00   90.00      .64      .12      .052      .052      .052       .21     36.96
     0.00      .17     0.00   90.00      .80      .13      .047      .046      .047       .27     41.33
     0.00      .19     0.00   90.00      .98      .14      .042      .041      .042       .33     45.71
     0.00      .22     0.00   90.00     1.38      .17      .035      .034      .035       .46     54.47
     0.00      .26     0.00   90.00     1.84      .20      .030      .029      .030       .62     63.23
     0.00      .30     0.00   90.00     2.36      .23      .027      .024      .027       .81     71.99
     0.00      .33      .01   90.00     2.91      .25      .024      .020      .024      1.02     80.75
```

```
     0.00     .40      .01   90.00     4.05       .31     .020      .014      .020       1.50    98.28
     0.00     .44      .01   90.00     4.58       .34     .018      .010      .018       1.78   107.05
     0.00     .47      .02   90.00     5.03       .36     .017      .007      .017       2.09   115.83
     0.00     .51      .02   90.00     5.38       .39     .016      .004      .015       2.41   124.60
     0.00     .54      .02   90.00     5.56       .42     .015      .001      .014       2.76   133.38

    PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

     0.00     .57      .03   90.00     5.56       .44     .014     -.001      .014       3.09   141.06
     0.00     .59      .03   90.00     5.47       .46     .013     -.003      .013       3.28   145.45
     0.00     .61      .03   90.00     5.33       .47     .013     -.004      .013       3.49   149.83
     0.00     .63      .03   90.00     5.11       .48     .013     -.005      .012       3.69   154.22
     0.00     .64      .03   90.00     4.82       .50     .012     -.006      .012       3.90   158.61
     0.00     .66      .03   90.00     4.45       .51     .012     -.007      .012       4.12   162.99
     0.00     .68      .03   90.00     4.02       .53     .012     -.008      .012       4.35   167.38
     0.00     .70      .04   90.00     3.50       .54     .011     -.009      .011       4.58   171.76
     0.00     .71      .04   90.00     2.92       .55     .011     -.009      .011       4.82   176.14
     0.00     .73      .04   90.00     2.27       .57     .011     -.010      .011       5.06   180.52
     0.00     .75      .04   90.00     1.57       .58     .010     -.010      .010       5.31   184.90
     0.00     .77      .04   90.00      .82       .59     .010     -.010      .010       5.56   189.28
     0.00     .78      .04   90.00      .04       .61     .010     -.010      .010       5.83   193.66

    PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT

    TRAPPING LEVEL=   1.98 METERS BELOW SURFACE,  DILUTION= 137.08
1
  UNIVERSAL DATA FILE: STRATHOR4.DAT

  #11 Simulation of Wong's Stratified Flow data,Run 1005-83
  0 1 0 0 0 0 0
 0.0000258         1  .00221   0.         2.
        0.       90.       1000.
         2    1.0000        0.
     00.00 1.01306    0.0
     00.00 1.01306    0.0
1
                              PROGRAM UDKHDEN
                    SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
                    AMBIENT CURRENTS AND VERTICAL GRADIENTS.   AUG 1985

    UNIVERSAL DATA FILE: STRATHOR4.DAT
    CASE I.D.  #11 Simulation of Wong's Stratified Flow data,Run 1005-83

          SINGLE PORT DISCHARGE CASE
    DISCHARGE= 0.0000 CU-M/S  DENSITY=1.00000 G/CM3  ** DIAMETER=  .0022-M
    ** NUMBER OF PORTS=   1  ** SPACING=1000.00-M  ** DEPTH=   2.00-M
0          AMBIENT STRATIFICATION PROFILE
     DEPTH (M)    DENSITY (G/CM3)   VELOCITY (M/S)
         .00        1.01306            .000
       10.00         .00000            .000
0   FROUDE NO=104.97,  PORT SPACING/PORT DIA= 452488.69,
+                                                STARTING LENGTH=     .013

    ALL LENGTHS ARE IN METERS-TIME IN SEC.  FIRST LINE ARE INITIAL CONDITIONS.
      X       Y       Z      TH1     TH2     WIDTH     DUCL     DRHO     DCCL      TIME   DILUTION
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```
     0.00      .01     0.00   90.00       .04       .01    1.000    1.000    1.000      0.00      1.93
     0.00      .03     0.00   90.00       .21       .02     .305     .305     .305       .01      6.30
     0.00      .05     0.00   90.00       .57       .03     .180     .180     .180       .02     10.68
     0.00      .07     0.00   90.00      1.11       .05     .128     .128     .128       .04     15.06
     0.00      .08     0.00   90.00      1.83       .06     .099     .098     .099       .06     19.44
     0.00      .10     0.00   90.00      2.73       .07     .081     .080     .081       .09     23.82
     0.00      .12     0.00   90.00      3.79       .09     .068     .066     .068       .12     28.20
     0.00      .14     0.00   90.00      5.01       .10     .059     .056     .059       .17     32.59
     0.00      .15      .01   90.00      6.35       .12     .052     .048     .052       .21     36.98
     0.00      .17      .01   90.00      7.79       .13     .047     .041     .047       .27     41.37
     0.00      .19      .01   90.00      9.28       .14     .043     .034     .042       .33     45.78
     0.00      .22      .02   90.00     12.18       .17     .036     .022     .035       .46     54.61
     0.00      .26      .03   90.00     14.49       .20     .031     .011     .030       .62     63.49
     0.00      .29      .03   90.00     15.55       .22     .028     .001     .027       .80     72.40

    PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

     0.00      .31      .04   90.00     15.27       .24     .026    -.005     .025       .92     77.98
     0.00      .33      .04   90.00     14.36       .25     .024    -.009     .023      1.03     82.43
     0.00      .35      .05   90.00     12.75       .27     .023    -.013     .022      1.14     86.87
     0.00      .37      .05   90.00     10.40       .28     .021    -.016     .021      1.26     91.29
     0.00      .38      .06   90.00      7.27       .30     .020    -.018     .020      1.38     95.70
     0.00      .40      .06   90.00      3.47       .31     .019    -.019     .019      1.52    100.09
     0.00      .42      .06   90.00      -.79       .33     .018    -.018     .018      1.66    104.47

    PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT

    TRAPPING LEVEL=   1.96 METERS BELOW SURFACE,  DILUTION=  73.30
    1
  UNIVERSAL DATA FILE: STRATHOR3.DAT

  #12 Simulation of Wong's Stratified Flow data, Run 0927-83
  0 1 0 0 0 0 0
 0.0000122         1  .00221   0.         2.
       0.       90.        1000.
        2    1.0000         0.
     00.00 0.99562    0.0
    10.0   1.04569     0.
1
                                         PROGRAM UDKHDEN
                           SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
                           AMBIENT CURRENTS AND VERTICAL GRADIENTS.   AUG 1985

    UNIVERSAL DATA FILE: STRATHOR3.DAT
    CASE I.D.  #12 Simulation of Wong's Stratified Flow data, Run 0927-83

         SINGLE PORT DISCHARGE CASE
    DISCHARGE= 0.0000 CU-M/S  DENSITY=1.00000 G/CM3  ** DIAMETER=  .0022-M
    ** NUMBER OF PORTS=   1  ** SPACING=1000.00-M  ** DEPTH=   2.00-M
0         AMBIENT STRATIFICATION PROFILE
     DEPTH (M)    DENSITY (G/CM3)   VELOCITY (M/S)
          .00          .99562           .000
        10.00         1.04569           .000
0   FROUDE NO=287.92,  PORT SPACING/PORT DIA= 452488.69,
+                                                         STARTING LENGTH=     .013
```

```
       X         Y         Z       TH1       TH2     WIDTH      DUCL      DRHO      DCCL        TIME    DILUTIOǸ

      .00       .00       .00    90.00       .00      0.00     1.000     1.000     1.000         .00       1.00
     0.00       .01      0.00    90.00       .01       .01     1.000     1.000     1.000        0.00       1.93
     0.00       .03      0.00    90.00       .03       .02      .305      .305      .305         .02       6.30
     0.00       .05      0.00    90.00       .08       .03      .180      .180      .180         .04      10.68
     0.00       .07      0.00    90.00       .15       .05      .128      .128      .128         .08      15.06
     0.00       .08      0.00    90.00       .24       .06      .099      .099      .099         .13      19.44
     0.00       .10      0.00    90.00       .36       .07      .081      .081      .081         .19      23.82
     0.00       .12      0.00    90.00       .51       .09      .068      .068      .068         .26      28.20
     0.00       .14      0.00    90.00       .68       .10      .059      .058      .059         .35      32.58
     0.00       .15      0.00    90.00       .87       .12      .052      .051      .052         .45      36.96
     0.00       .17      0.00    90.00      1.08       .13      .047      .045      .047         .57      41.33
     0.00       .19      0.00    90.00      1.32       .14      .042      .040      .042         .69      45.71
     0.00       .22      0.00    90.00      1.84       .17      .035      .032      .035         .98      54.47
     0.00       .26      0.00    90.00      2.42       .20      .030      .026      .030        1.32      63.23
     0.00       .30       .01    90.00      3.01       .23      .027      .020      .027        1.71      72.00
     0.00       .33       .01    90.00      3.59       .25      .024      .014      .024        2.15      80.76
     0.00       .37       .01    90.00      4.08       .28      .022      .009      .022        2.64      89.53
     0.00       .40       .01    90.00      4.41       .31      .020      .004      .020        3.18      98.30

    PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

     0.00       .44       .02    90.00      4.50       .34      .018     -.001      .018        3.77     107.07
     0.00       .45       .02    90.00      4.43       .35      .017     -.003      .017        4.09     111.45
     0.00       .47       .02    90.00      4.27       .36      .017     -.005      .017        4.41     115.84
     0.00       .49       .02    90.00      4.02       .38      .016     -.007      .016        4.75     120.22
     0.00       .51       .02    90.00      3.67       .39      .015     -.009      .015        5.10     124.60
     0.00       .52       .02    90.00      3.22       .40      .015     -.010      .015        5.47     128.99
     0.00       .54       .02    90.00      2.67       .42      .014     -.012      .014        5.85     133.37
     0.00       .56       .02    90.00      2.03       .43      .014     -.012      .014        6.24     137.75
     0.00       .58       .02    90.00      1.31       .45      .014     -.013      .014        6.64     142.13
     0.00       .60       .02    90.00       .52       .46      .013     -.013      .013        7.06     146.51
     0.00       .61       .02    90.00      -.31       .47      .013     -.013      .013        7.49     150.89

    PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT

    TRAPPING LEVEL=    1.99 METERS BELOW SURFACE,   DILUTION= 105.55
1
  UNIVERSAL DATA FILE: STRATHOR3.DAT

  #13 Simulation of Wong's Stratified Flow data, Run 0505-83
  0 1 0 0 0 0 0
 0.0000199          1  .00511   0.         2.
        0.       90.       1000.
         2    1.0000         0.
     00.00 0.99450     0.0
    10.0   1.024790     0.0
1
                                 PROGRAM UDKHDEN
                       SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
                       AMBIENT CURRENTS AND VERTICAL GRADIENTS.   AUG 1985

    UNIVERSAL DATA FILE: STRATHOR3.DAT
    CASE I.D.  #13 Simulation of Wong's Stratified Flow data, Run 0505-83
```

```
    DISCHARGE= 0.0000 CU-M/S  DENSITY=1.00000 G/CM3  ** DIAMETER=  .0051-M
    ** NUMBER OF PORTS=   1  ** SPACING=1000.00-M  ** DEPTH=   2.00-M
0          AMBIENT STRATIFICATION PROFILE
     DEPTH (M)    DENSITY (G/CM3)   VELOCITY (M/S)
         .00          .99450            .000
       10.00         1.02479            .000
0   FROUDE NO=183.56,  PORT SPACING/PORT DIA= 195694.72,
+                                                         STARTING LENGTH=     .030

    ALL LENGTHS ARE IN METERS-TIME IN SEC.  FIRST LINE ARE INITIAL CONDITIONS.
      X        Y        Z       TH1      TH2      WIDTH     DUCL      DRHO      DCCL       TIME    DILUTIO

     .00      .00      .00    90.00      .00       .01     1.000     1.000     1.000       .00      1.00
    0.00      .03     0.00    90.00      .01       .01     1.000     1.000     1.000       .03      1.93
    0.00      .07     0.00    90.00      .07       .05      .305      .305      .305       .12      6.30
    0.00      .11     0.00    90.00      .19       .08      .180      .179      .180       .30     10.68
    0.00      .15     0.00    90.00      .36       .11      .128      .125      .128       .58     15.06
    0.00      .19     0.00    90.00      .59       .14      .099      .094      .099       .96     19.44
    0.00      .23     0.00    90.00      .86       .17      .081      .072      .081      1.43     23.82
    0.00      .27     0.00    90.00     1.16       .20      .068      .054      .068      2.00     28.20
    0.00      .32     0.00    90.00     1.46       .24      .059      .037      .059      2.67     32.58
    0.00      .36     0.00    90.00     1.71       .27      .052      .022      .052      3.43     36.96
    0.00      .40      .01    90.00     1.86       .30      .047      .007      .047      4.28     41.34

    PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

    0.00      .44      .01    90.00     1.85       .33      .042     -.007      .042      5.24     45.72
    0.00      .48      .01    90.00     1.63       .36      .038     -.019      .038      6.28     50.10
    0.00      .52      .01    90.00     1.17       .40      .035     -.028      .035      7.43     54.48
    0.00      .56      .01    90.00      .47       .43      .033     -.032      .033      8.67     58.85

    PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT

    TRAPPING LEVEL=   1.99 METERS BELOW SURFACE,  DILUTION=  43.38
1
  UNIVERSAL DATA FILE: STRATHOR3.DAT

  #14 Simulation of Wong's Stratified Flow data, Run 0510-83
  0 1 0 0 0 0 0
 0.0000292          1  .00511   0.         2.
        0.       90.       1000.
         2    1.0000        0.
      00.00 0.99266    0.0
    10.0   1.032842     0.0
1
                              PROGRAM UDKHDEN
                     SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
                     AMBIENT CURRENTS AND VERTICAL GRADIENTS.   AUG 1985

    UNIVERSAL DATA FILE: STRATHOR3.DAT
    CASE I.D.  #14 Simulation of Wong's Stratified Flow data, Run 0510-83

         SINGLE PORT DISCHARGE CASE
    DISCHARGE= 0.0000 CU-M/S  DENSITY=1.00000 G/CM3  ** DIAMETER=  .0051-M
    ** NUMBER OF PORTS=   1  ** SPACING=1000.00-M  ** DEPTH=   2.00-M
0          AMBIENT STRATIFICATION PROFILE
```

```
          .00          .99266            .000
        10.00        1.03284            .000
0   FROUDE NO=241.10,  PORT SPACING/PORT DIA= 195694.72,
+                                                               STARTING LENGTH=     .030

    ALL LENGTHS ARE IN METERS-TIME IN SEC.  FIRST LINE ARE INITIAL CONDITIONS.
      X       Y        Z       TH1      TH2     WIDTH     DUCL     DRHO     DCCL       TIME   DILUTION

     .00     .00      .00    90.00      .00      .01    1.000    1.000    1.000       .00     1.00
    0.00     .03     0.00    90.00      .01      .01    1.000    1.000    1.000       .02     1.93
    0.00     .07     0.00    90.00      .04      .05     .305     .305     .305       .08     6.30
    0.00     .11     0.00    90.00      .11      .08     .180     .180     .180       .21    10.68
    0.00     .15     0.00    90.00      .21      .11     .128     .126     .128       .40    15.06
    0.00     .19     0.00    90.00      .34      .14     .099     .096     .099       .66    19.44
    0.00     .23     0.00    90.00      .51      .17     .081     .075     .081       .98    23.82
    0.00     .27     0.00    90.00      .69      .20     .068     .059     .068      1.37    28.20
    0.00     .32     0.00    90.00      .89      .24     .059     .045     .059      1.82    32.58
    0.00     .36     0.00    90.00     1.09      .27     .052     .033     .052      2.34    36.96
    0.00     .40     0.00    90.00     1.25      .30     .047     .020     .047      2.92    41.33
    0.00     .44     0.00    90.00     1.36      .33     .042     .008     .042      3.57    45.71

    PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

    0.00     .50      .01    90.00     1.36      .38     .037    -.008     .037      4.66    52.28
    0.00     .54      .01    90.00     1.20      .41     .034    -.017     .034      5.48    56.66
    0.00     .58      .01    90.00      .90      .44     .032    -.024     .032      6.35    61.04
    0.00     .62      .01    90.00      .47      .48     .029    -.028     .029      7.29    65.42
    0.00     .66      .01    90.00     -.06      .51     .028    -.028     .028      8.30    69.80

    PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT

    TRAPPING LEVEL=   2.00 METERS BELOW SURFACE,  DILUTION=  48.99
1
  UNIVERSAL DATA FILE: STRATHOR3.DAT

  #15 Simulation of Wong's Stratified Flow data, Run 0513-83
  0 1 0 0 0 0 0
 0.0000113          1  .00221   0.         2.
        0.       90.       1000.
         2    1.0000        0.
      00.00 0.99212    0.0
      00.00 0.99212    0.0
1
                                     PROGRAM UDKHDEN
                         SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
                         AMBIENT CURRENTS AND VERTICAL GRADIENTS.   AUG 1985

    UNIVERSAL DATA FILE: STRATHOR3.DAT
    CASE I.D.  #15 Simulation of Wong's Stratified Flow data, Run 0513-83

          SINGLE PORT DISCHARGE CASE
    DISCHARGE= 0.0000 CU-M/S  DENSITY=1.00000 G/CM3  ** DIAMETER=  .0022-M
    ** NUMBER OF PORTS=   1  ** SPACING=1000.00-M  ** DEPTH=   2.00-M
0          AMBIENT STRATIFICATION PROFILE
     DEPTH (M)     DENSITY (G/CM3)   VELOCITY (M/S)
```

```
0   FROUDE NO= 44.07,  PORT SPACING/PORT DIA= 452488.69,
+                                                           STARTING LENGTH=     .013

    ALL LENGTHS ARE IN METERS-TIME IN SEC.  FIRST LINE ARE INITIAL CONDITIONS.
      X        Y        Z       TH1      TH2     WIDTH     DUCL      DRHO      DCCL       TIME   DILUTION

     .00      .00      .00     90.00      .00     0.00     1.000     1.000     1.000       .00      1.00
    0.00      .01     0.00     90.00      .24      .01     1.000     1.000     1.000      0.00      1.93
    0.00      .03     0.00     90.00     1.22      .02      .306      .305      .305       .02      6.30
    0.00      .05     0.00     90.00     3.23      .03      .181      .180      .180       .04     10.69
    0.00      .07     0.00     90.00     6.25      .05      .129      .126      .128       .08     15.07
    0.00      .08     0.00     90.00    10.15      .06      .100      .096      .099       .14     19.47
    0.00      .10      .01     90.00    14.71      .07      .083      .075      .081       .20     23.90
    0.00      .12      .01     90.00    19.57      .09      .072      .058      .068       .28     28.38
    0.00      .13      .02     90.00    24.31      .10      .064      .045      .058       .37     32.93
    0.00      .15      .03     90.00    28.53      .11      .058      .032      .051       .47     37.55
    0.00      .16      .04     90.00    31.88      .12      .054      .021      .046       .57     42.26
    0.00      .18      .05     90.00    34.12      .13      .049      .010      .041       .69     47.04

    PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

    0.00      .21      .06     90.00    34.53      .16      .042     -.006      .035       .92     55.49
    0.00      .22      .07     90.00    31.93      .17      .038     -.015      .032      1.07     60.28
    0.00      .24      .08     90.00    26.05      .19      .033     -.021      .030      1.24     64.97
    0.00      .25      .09     90.00    15.26      .21      .029     -.026      .028      1.44     69.50
    0.00      .27      .09     90.00     -.83      .23      .026     -.026      .026      1.66     73.91

    PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT

    TRAPPING LEVEL=   1.94 METERS BELOW SURFACE,  DILUTION=  52.10
```

APPENDIX 1

LISTING OF UDKHDEN COMPUTER OUTPUTS

D. DIFFUSER DISCHARGES IN STRATIFIED AMBIENT FLUIDS

```
1
  UNIVERSAL DATA FILE: DIFFUSER1.DAT

  #1 Simulation of Wright, et al diffuser data, Run 5-7-B
  0 1 0 0 0 0 0
 0.0000878        10  .00953   0.        1.
       0.     90.        0.051
         2    1.0000        0.
      00.00 1.01681    0.0
    1.00   1.02120     0.
1
                                  PROGRAM UDKHDEN
                       SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
                       AMBIENT CURRENTS AND VERTICAL GRADIENTS.   AUG 1985

    UNIVERSAL DATA FILE: DIFFUSER1.DAT
    CASE I.D.  #1 Simulation of Wright, et al diffuser data, Run 5-7-B
    DISCHARGE=  .0001 CU-M/S  DENSITY=1.00000 G/CM3  ** DIAMETER=  .0095-M
    ** NUMBER OF PORTS=  10  ** SPACING=    .05-M  ** DEPTH=   1.00-M
0         AMBIENT STRATIFICATION PROFILE
     DEPTH (M)    DENSITY (G/CM3)   VELOCITY (M/S)
         .00        1.01681            .000
        1.00        1.02120            .000
0   FROUDE NO=  2.77,  PORT SPACING/PORT DIA=      5.35,
+                                                          STARTING LENGTH=     .047

    ALL LENGTHS ARE IN METERS-TIME IN SEC.  FIRST LINE ARE INITIAL CONDITIONS.
      X       Y       Z      TH1     TH2     WIDTH     DUCL     DRHO     DCCL      TIME   DILUTIO

      .00     .00     .00   90.00     .00      .01    1.000    1.000    1.000       .00     1.00
     0.00     .05     .02   90.00   47.43      .03    1.000     .673     .677       .43     2.84

    PLUMES MERGING

     0.00     .08     .09   90.00   73.61      .06     .810     .210     .230      1.16     8.36
     0.00     .10     .16   90.00   79.68      .08     .794     .107     .143      1.93    13.02
     0.00     .11     .24   90.00   81.97      .09     .695     .050     .098      2.75    17.15
     0.00     .12     .31   90.00   82.91      .12     .557     .015     .069      3.74    20.54

    PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

     0.00     .13     .39   90.00   83.01      .15     .497    -.008     .061      4.91    23.33
     0.00     .14     .46   90.00   81.92      .20     .391    -.029     .055      6.29    25.69
     0.00     .15     .54   90.00   71.89      .48     .167    -.048     .052      8.48    27.30

    PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT

    TRAPPING LEVEL=    .64 METERS BELOW SURFACE,  DILUTION=  22.34
1
  UNIVERSAL DATA FILE: DIFFUSER1.DAT

  #2 Simulation of Wright, et al diffuser data,Run 5-8-A
  0 1 0 0 0 0 0
 0.0001020        10  .00953   0.        1.
       0.     90.        0.305
         2    1.0000        0
```

```
    1.00  1.02030    0.0

  COMPUTATIONS CEASE FOR
  CASE I.D.  #2 Simulation of Wright, et al diffuser data,Run 5-8-A

  CORRECT THE FOLLOWING AND REENTER DATA.
  EFFLUENT DENSITY MUST BE .LE. AMBIENT DENSITY AT THE DISCHARGE DEPTH

  GOING TO NEXT DATA SET IF THERE IS ONE.
1
  UNIVERSAL DATA FILE: DIFFUSER1.DAT

  #3 Simulation of Wright, et al diffuser data, Run 5-8-B
  0 1 0 0 0 0 0
 0.0000971         10  .00953   0.         1.
      0.      90.       0.152
         2    1.0000        0.
     00.00 1.013297    0.0
    1.00   1.02120     0.0
1
                                     PROGRAM UDKHDEN
                       SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
                       AMBIENT CURRENTS AND VERTICAL GRADIENTS.   AUG 1985

    UNIVERSAL DATA FILE: DIFFUSER1.DAT
    CASE I.D.  #3 Simulation of Wright, et al diffuser data, Run 5-8-B
    DISCHARGE=  .0001 CU-M/S  DENSITY=1.00000 G/CM3  ** DIAMETER=  .0095-M
    ** NUMBER OF PORTS=  10  ** SPACING=    .15-M  ** DEPTH=   1.00-M
0          AMBIENT STRATIFICATION PROFILE
     DEPTH (M)    DENSITY (G/CM3)   VELOCITY (M/S)
          .00        1.01330            .000
         1.00        1.02120            .000
0   FROUDE NO=  3.06,  PORT SPACING/PORT DIA=     15.95,
+                                                    STARTING LENGTH=     .048

    ALL LENGTHS ARE IN METERS-TIME IN SEC.  FIRST LINE ARE INITIAL CONDITIONS.
      X       Y       Z      TH1     TH2     WIDTH     DUCL     DRHO     DCCL      TIME   DILUTION

      .00     .00     .00   90.00     .00      .01    1.000    1.000    1.000       .00     1.00
     0.00     .05     .02   90.00   39.92      .03    1.000     .759     .765       .38     2.51
     0.00     .09     .08   90.00   70.85      .07     .673     .191     .223      1.11     8.62
     0.00     .11     .15   90.00   78.26      .10     .549     .058     .113      2.03    16.94

    PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

     0.00     .12     .23   90.00   79.81      .15     .405    -.007     .073      3.20    26.41

    PLUMES MERGING

     0.00     .13     .29   90.00   72.93      .24     .189    -.046     .056      4.82    32.26
     0.00     .15     .31   90.00  -60.63      .46     .078    -.042     .043      6.89    32.94

    PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT

    TRAPPING LEVEL=    .78 METERS BELOW SURFACE,  DILUTION=  25.16
1
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```
  #4 Simulation of Wright, et al diffuser data, Run 5-8-C
  0 1 0 0 0 0 0
 0.0001730         10  .00953   0.         1.
      0.    90.       0.203
         2    1.0000        0.
     00.00 1.01622    0.0
   1.00   1.02380     0.0
1
                                          PROGRAM UDKHDEN
                         SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
                         AMBIENT CURRENTS AND VERTICAL GRADIENTS.   AUG 1985

    UNIVERSAL DATA FILE: DIFFUSER1.DAT
    CASE I.D.  #4 Simulation of Wright, et al diffuser data, Run 5-8-C
    DISCHARGE=  .0002 CU-M/S  DENSITY=1.00000 G/CM3  ** DIAMETER=  .0095-M
    ** NUMBER OF PORTS=  10  ** SPACING=    .20-M  ** DEPTH=   1.00-M
0           AMBIENT STRATIFICATION PROFILE
     DEPTH (M)    DENSITY (G/CM3)   VELOCITY (M/S)
         .00        1.01622            .000
        1.00        1.02380            .000
0   FROUDE NO=  5.14,  PORT SPACING/PORT DIA=     21.30,
+                                                          STARTING LENGTH=     .054

    ALL LENGTHS ARE IN METERS-TIME IN SEC.  FIRST LINE ARE INITIAL CONDITIONS.
      X       Y       Z      TH1      TH2     WIDTH    DUCL     DRHO     DCCL      TIME   DILUTION

     .00     .00     .00   90.00      .00      .01    1.000    1.000    1.000       .00     1.00
    0.00     .05     .01   90.00    16.87      .03    1.000     .954     .956       .23     2.01
    0.00     .12     .05   90.00    52.26      .07     .459     .263     .282       .76     6.83
    0.00     .15     .12   90.00    67.92      .11     .391     .107     .148      1.51    12.99
    0.00     .18     .19   90.00    73.40      .15     .329     .032     .095      2.38    20.30

    PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

    0.00     .20     .26   90.00    73.96      .20     .246    -.015     .069      3.47    28.07

    PLUMES MERGING

    0.00     .22     .33   90.00    53.03      .37     .086    -.048     .052      5.33    33.01

    PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT

    TRAPPING LEVEL=    .76 METERS BELOW SURFACE,  DILUTION=  25.30
1
  UNIVERSAL DATA FILE: DIFFUSER1.DAT

  #5 Simulation of Wright, et al diffuser data,Run 5-9-A
  0 1 0 0 0 0 0
 0.0000560         10  .00318   0.         1.
      0.    90.       0.102.
         2    1.0000        0.
     00.00 1.02076    0.0
   1.00   1.02420     0.0
1
                                          PROGRAM UDKHDEN
```

```
                      AMBIENT CURRENTS AND VERTICAL GRADIENTS.   AUG 1985

    UNIVERSAL DATA FILE: DIFFUSER1.DAT
    CASE I.D.  #5 Simulation of Wright, et al diffuser data,Run 5-9-A
    DISCHARGE=  .0001 CU-M/S  DENSITY=1.00000 G/CM3  ** DIAMETER=  .0032-M
    ** NUMBER OF PORTS=  10  ** SPACING=    .10-M  ** DEPTH=   1.00-M
0         AMBIENT STRATIFICATION PROFILE
     DEPTH (M)    DENSITY (G/CM3)   VELOCITY (M/S)
         .00        1.02076            .000
        1.00        1.02420            .000
0   FROUDE NO= 25.67,  PORT SPACING/PORT DIA=     32.08,
+                                                      STARTING LENGTH=     .019

    ALL LENGTHS ARE IN METERS-TIME IN SEC.  FIRST LINE ARE INITIAL CONDITIONS.
      X       Y       Z      TH1     TH2     WIDTH     DUCL     DRHO     DCCL      TIME   DILUTION

     .00     .00     .00   90.00     .00     0.00    1.000    1.000    1.000       .00     1.00
    0.00     .02    0.00   90.00     .70      .01    1.000    1.000    1.000       .03     1.93
    0.00     .04    0.00   90.00    3.56      .03     .309     .308     .308       .10     6.24
    0.00     .07    0.00   90.00    9.32      .05     .186     .182     .183       .26    10.51
    0.00     .09     .01   90.00   17.39      .07     .137     .129     .130       .49    14.76
    0.00     .12     .02   90.00   26.56      .08     .113     .097     .101       .78    19.05
    0.00     .14     .03   90.00   35.38      .10     .101     .076     .082      1.12    23.46

    PLUMES MERGING

    0.00     .16     .05   90.00   42.86      .11     .094     .060     .069      1.49    27.77
    0.00     .18     .07   90.00   48.65      .12     .093     .048     .061      1.88    31.36
    0.00     .19     .09   90.00   52.97      .12     .092     .038     .055      2.27    34.72
    0.00     .21     .11   90.00   56.15      .13     .091     .030     .051      2.67    37.95
    0.00     .22     .13   90.00   58.45      .13     .089     .022     .047      3.07    41.06
    0.00     .25     .17   90.00   61.04      .15     .082     .008     .040      3.91    46.88

    PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

    0.00     .27     .21   90.00   61.41      .17     .073    -.003     .035      4.72    51.39
    0.00     .28     .23   90.00   60.72      .18     .065    -.008     .032      5.24    53.66
    0.00     .29     .26   90.00   59.10      .20     .056    -.012     .029      5.83    55.62
    0.00     .31     .28   90.00   56.02      .21     .048    -.016     .027      6.54    57.26
    0.00     .32     .30   90.00   50.11      .27     .038    -.019     .024      7.41    58.60
    0.00     .34     .32   90.00   37.38      .35     .030    -.022     .024      8.48    59.66
    0.00     .36     .33   90.00    7.12      .44     .024    -.024     .024      9.85    60.49

    PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT

    TRAPPING LEVEL=    .80 METERS BELOW SURFACE,  DILUTION=  50.14
1
  UNIVERSAL DATA FILE: DIFFUSER1.DAT

  #6 Simulation of Wright, et al diffuser data, Run 5-9-B
  0 1 0 0 0 0 0
 0.0000303         10  .00318   0.         1.
      0.     90.       0.051
         2    1.0000        0.
     00.00 1.01879    0.0
   1.00   1.02380      0
```

```
                                        PROGRAM UDKHDEN
                          SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
                          AMBIENT CURRENTS AND VERTICAL GRADIENTS.   AUG 1985

    UNIVERSAL DATA FILE: DIFFUSER1.DAT
    CASE I.D.  #6 Simulation of Wright, et al diffuser data, Run 5-9-B
    DISCHARGE= 0.0000 CU-M/S  DENSITY=1.00000 G/CM3  ** DIAMETER=  .0032-M
    ** NUMBER OF PORTS=  10  ** SPACING=    .05-M  ** DEPTH=   1.00-M
0          AMBIENT STRATIFICATION PROFILE
     DEPTH (M)    DENSITY (G/CM3)   VELOCITY (M/S)
         .00        1.01879            .000
        1.00        1.02380            .000
0   FROUDE NO= 14.01,  PORT SPACING/PORT DIA=     16.04,
+                                                       STARTING LENGTH=     .019

    ALL LENGTHS ARE IN METERS-TIME IN SEC.  FIRST LINE ARE INITIAL CONDITIONS.
      X        Y        Z      TH1      TH2     WIDTH     DUCL     DRHO     DCCL       TIME   DILUTION

      .00     .00      .00    90.00      .00     0.00    1.000    1.000    1.000       .00      1.00
     0.00     .02     0.00    90.00     2.37      .01    1.000     .999     .999       .05      1.93
     0.00     .04     0.00    90.00    11.71      .03     .317     .310     .311       .19      6.20
     0.00     .07      .01    90.00    27.70      .04     .208     .181     .184       .45     10.47

    PLUMES MERGING

     0.00     .09      .03    90.00    42.87      .06     .180     .125     .132       .81     14.57
     0.00     .11      .05    90.00    53.08      .06     .179     .095     .108      1.18     17.85
     0.00     .12      .07    90.00    59.50      .07     .179     .072     .091      1.55     20.97
     0.00     .13      .09    90.00    63.67      .07     .177     .054     .079      1.93     24.00
     0.00     .14      .11    90.00    66.46      .08     .171     .039     .069      2.31     26.91
     0.00     .15      .14    90.00    68.31      .08     .162     .025     .060      2.71     29.65
     0.00     .16      .16    90.00    69.48      .09     .149     .014     .053      3.14     32.19
     0.00     .17      .18    90.00    70.07      .10     .133     .004     .046      3.61     34.48

    PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

     0.00     .18      .22    90.00    69.88      .12     .110    -.007     .038      4.42     37.44
     0.00     .19      .24    90.00    68.82      .14     .101    -.013     .036      5.05     39.09
     0.00     .20      .27    90.00    66.42      .16     .088    -.020     .035      5.76     40.56
     0.00     .21      .29    90.00    60.92      .21     .070    -.026     .034      6.61     41.80
     0.00     .23      .31    90.00    42.59      .32     .045    -.032     .033      7.77     42.72

    PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT

    TRAPPING LEVEL=    .80 METERS BELOW SURFACE,  DILUTION=  35.64
1
  UNIVERSAL DATA FILE: DIFFUSER1.DAT

  #7 Simulation of Wright, et al diffuser data, Run 5-9-C
  0 1 0 0 0 0 0
 0.0001190        10  .00318   0.        1.
      0.      90.     0.203
         2    1.0000        0.
      00.00 1.01883    0.0
    1.00   1.02310     0.
1
```

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                    SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
                    AMBIENT CURRENTS AND VERTICAL GRADIENTS.   AUG 1985

   UNIVERSAL DATA FILE: DIFFUSER1.DAT
   CASE I.D.  #7 Simulation of Wright, et al diffuser data, Run 5-9-C
   DISCHARGE=  .0001 CU-M/S  DENSITY=1.00000 G/CM3  ** DIAMETER=  .0032-M
   ** NUMBER OF PORTS=  10  ** SPACING=    .20-M  ** DEPTH=   1.00-M
0         AMBIENT STRATIFICATION PROFILE
    DEPTH (M)    DENSITY (G/CM3)   VELOCITY (M/S)
        .00        1.01883            .000
       1.00        1.02310            .000
0  FROUDE NO= 55.84,  PORT SPACING/PORT DIA=     63.84,
+                                                     STARTING LENGTH=     .018

   ALL LENGTHS ARE IN METERS-TIME IN SEC.  FIRST LINE ARE INITIAL CONDITIONS.
     X       Y       Z      TH1      TH2     WIDTH     DUCL     DRHO     DCCL       TIME   DILUTION

     .00     .00     .00   90.00      .00     0.00    1.000    1.000    1.000        .00     1.00
    0.00     .02    0.00   90.00      .15      .01    1.000    1.000    1.000        .01     1.93
    0.00     .04    0.00   90.00      .76      .03     .307     .307     .307        .05     6.27
    0.00     .07    0.00   90.00     2.01      .05     .182     .182     .182        .12    10.59
    0.00     .09    0.00   90.00     3.88      .07     .130     .129     .129        .23    14.88
    0.00     .12    0.00   90.00     6.36      .09     .101     .100     .101        .38    19.13
    0.00     .15     .01   90.00     9.36      .10     .084     .080     .082        .57    23.37
    0.00     .17     .01   90.00    12.80      .12     .072     .066     .070        .79    27.59
    0.00     .19     .02   90.00    16.53      .14     .063     .055     .061       1.04    31.82
    0.00     .22     .03   90.00    20.36      .16     .057     .046     .053       1.33    36.05
    0.00     .24     .04   90.00    24.10      .17     .052     .038     .048       1.64    40.30
    0.00     .27     .05   90.00    27.57      .19     .049     .031     .043       1.97    44.59

   PLUMES MERGING

    0.00     .31     .07   90.00    33.11      .22     .044     .017     .037       2.71    52.56
    0.00     .35     .10   90.00    36.13      .24     .040     .006     .033       3.52    58.82

   PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

    0.00     .39     .13   90.00    36.36      .26     .037    -.004     .030       4.28    63.63
    0.00     .41     .14   90.00    35.28      .27     .035    -.009     .029       4.75    66.13
    0.00     .43     .16   90.00    33.08      .28     .033    -.013     .028       5.25    68.44
    0.00     .45     .17   90.00    29.46      .30     .030    -.017     .026       5.78    70.56
    0.00     .47     .18   90.00    23.99      .32     .028    -.020     .025       6.37    72.47
    0.00     .50     .19   90.00    16.27      .34     .025    -.022     .024       7.02    74.17
    0.00     .52     .20   90.00     6.29      .36     .023    -.022     .022       7.74    75.69

   PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT

   TRAPPING LEVEL=    .88 METERS BELOW SURFACE,  DILUTION=  61.78
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1
  UNIVERSAL DATA FILE: DIFFUSER2.DAT

  #8 Simulation of Wright, et al diffuser data, Run 5-12-A
  0 1 0 0 0 0 0
 0.0001060        10  .00318   0.        1.
       0.     90.       0.305
          2   1.0000        0.
     00.00 1.01802    0.0
    1.00   1.02310     0.
1
                                  PROGRAM UDKHDEN
                        SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
                        AMBIENT CURRENTS AND VERTICAL GRADIENTS.   AUG 1985

    UNIVERSAL DATA FILE: DIFFUSER2.DAT
    CASE I.D.  #8 Simulation of Wright, et al diffuser data, Run 5-12-A
    DISCHARGE=  .0001 CU-M/S  DENSITY=1.00000 G/CM3  ** DIAMETER=  .0032-M
    ** NUMBER OF PORTS=  10  ** SPACING=    .30-M  ** DEPTH=   1.00-M
0          AMBIENT STRATIFICATION PROFILE
     DEPTH (M)    DENSITY (G/CM3)   VELOCITY (M/S)
          .00        1.01802             .000
         1.00        1.02310             .000
0   FROUDE NO= 49.74,  PORT SPACING/PORT DIA=     95.91,
+                                                         STARTING LENGTH=     .018

    ALL LENGTHS ARE IN METERS-TIME IN SEC.  FIRST LINE ARE INITIAL CONDITIONS.
      X        Y        Z       TH1      TH2     WIDTH     DUCL     DRHO     DCCL      TIME   DILUTION

      .00      .00      .00    90.00      .00    0.00    1.000    1.000    1.000       .00      1.00
     0.00      .02     0.00    90.00      .19     .01    1.000    1.000    1.000       .01      1.93
     0.00      .04     0.00    90.00      .95     .03     .307     .306     .306       .05      6.28
     0.00      .07     0.00    90.00     2.53     .05     .181     .181     .181       .14     10.62
     0.00      .09     0.00    90.00     4.90     .07     .129     .128     .129       .26     14.94
     0.00      .12      .01    90.00     8.00     .09     .101     .098     .100       .43     19.25
     0.00      .15      .01    90.00    11.72     .11     .084     .079     .082       .64     23.55
     0.00      .17      .02    90.00    15.88     .12     .072     .064     .069       .89     27.86
     0.00      .19      .02    90.00    20.23     .14     .064     .052     .060      1.17     32.20
     0.00      .22      .03    90.00    24.50     .16     .058     .042     .053      1.48     36.57
     0.00      .24      .04    90.00    28.43     .17     .053     .033     .047      1.83     41.00
     0.00      .26      .06    90.00    31.81     .19     .050     .025     .042      2.20     45.48
     0.00      .30      .09    90.00    36.37     .22     .044     .009     .035      3.02     54.60

    PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

     0.00      .34      .11    90.00    37.30     .25     .039    -.002     .031      3.83     62.64
     0.00      .36      .13    90.00    36.12     .27     .035    -.009     .029      4.34     67.20
     0.00      .38      .14    90.00    33.16     .30     .032    -.014     .027      4.91     71.67

    PLUMES MERGING

     0.00      .40      .16    90.00    27.63     .32     .029    -.019     .025      5.54     75.70
     0.00      .43      .17    90.00    18.48     .35     .026    -.022     .024      6.24     78.81
     0.00      .45      .17    90.00     5.22     .37     .024    -.023     .024      7.01     81.48

    PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT
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   TRAPPING LEVEL=    .89 METERS BELOW SURFACE,  DILUTION=  60.92
1
  UNIVERSAL DATA FILE: DIFFUSER2.DAT

  #9 Simulation of Wright, et al diffuser data,Run 5-12-B
  0 1 0 0 0 0 0
 0.0000668          10  .00318   0.         1.
       0.     90.       0.152
          2    1.0000         0.
      00.00 1.01917    0.0
    1.00   1.02360    0.0
1
                                               PROGRAM UDKHDEN
                              SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
                              AMBIENT CURRENTS AND VERTICAL GRADIENTS.   AUG 1985

    UNIVERSAL DATA FILE: DIFFUSER2.DAT
    CASE I.D.  #9 Simulation of Wright, et al diffuser data,Run 5-12-B
    DISCHARGE=  .0001 CU-M/S  DENSITY=1.00000 G/CM3  ** DIAMETER=  .0032-M
    ** NUMBER OF PORTS=  10  ** SPACING=    .15-M  ** DEPTH=   1.00-M
0          AMBIENT STRATIFICATION PROFILE
     DEPTH (M)    DENSITY (G/CM3)   VELOCITY (M/S)
          .00        1.01917             .000
         1.00        1.02360             .000
0   FROUDE NO= 31.01,  PORT SPACING/PORT DIA=     47.80,
+                                                             STARTING LENGTH=     .018

    ALL LENGTHS ARE IN METERS-TIME IN SEC.  FIRST LINE ARE INITIAL CONDITIONS.
      X        Y        Z       TH1      TH2     WIDTH      DUCL      DRHO      DCCL       TIME   DILUTION

      .00      .00      .00    90.00      .00     0.00     1.000     1.000     1.000       .00      1.00
     0.00      .02     0.00    90.00      .48      .01     1.000     1.000     1.000       .02      1.93
     0.00      .04     0.00    90.00     2.45      .03      .308      .307      .307       .09      6.26
     0.00      .07     0.00    90.00     6.45      .05      .183      .182      .182       .22     10.57
     0.00      .09      .01    90.00    12.26      .07      .133      .128      .130       .41     14.85
     0.00      .12      .01    90.00    19.35      .08      .107      .097      .101       .67     19.14
     0.00      .14      .02    90.00    26.87      .10      .092      .076      .082       .98     23.48
     0.00      .16      .04    90.00    33.94      .12      .083      .059      .069      1.32     27.93
     0.00      .18      .05    90.00    40.00      .13      .077      .046      .059      1.70     32.52
     0.00      .20      .07    90.00    44.85      .14      .073      .034      .052      2.11     37.26

    PLUMES MERGING

     0.00      .22      .09    90.00    48.52      .16      .069      .024      .046      2.53     42.13
     0.00      .24      .11    90.00    51.06      .17      .066      .015      .042      2.98     46.17

    PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

     0.00      .27      .15    90.00    53.01      .19      .060     -.001      .036      3.94     53.09
     0.00      .28      .17    90.00    52.32      .20      .056     -.008      .034      4.46     56.11
     0.00      .30      .19    90.00    50.08      .21      .050     -.014      .032      5.03     58.81
     0.00      .32      .21    90.00    45.33      .24      .043     -.020      .030      5.69     61.13
     0.00      .34      .22    90.00    35.63      .27      .033     -.023      .027      6.49     63.00
     0.00      .36      .23    90.00    15.62      .32      .025     -.023      .024      7.57     64.36

    PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT
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   TRAPPING LEVEL=    .85 METERS BELOW SURFACE,  DILUTION=  52.87
1
  UNIVERSAL DATA FILE: DIFFUSER2.DAT

  #10 Simulation of Wright, et al diffuser data, Run 5-12-C
  0 1 0 0 0 0 0
 0.0001160        10  .00318   0.         1.
      0.      90.      0.051
         2    1.0000        0.
     00.00 1.01925    0.0
   1.00   1.02430     0.0
1
                                  PROGRAM UDKHDEN
                      SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
                      AMBIENT CURRENTS AND VERTICAL GRADIENTS.   AUG 1985

   UNIVERSAL DATA FILE: DIFFUSER2.DAT
   CASE I.D.  #10 Simulation of Wright, et al diffuser data, Run 5-12-C
   DISCHARGE=  .0001 CU-M/S  DENSITY=1.00000 G/CM3  ** DIAMETER=  .0032-M
   ** NUMBER OF PORTS=  10  ** SPACING=    .05-M  ** DEPTH=   1.00-M
0         AMBIENT STRATIFICATION PROFILE
    DEPTH (M)    DENSITY (G/CM3)   VELOCITY (M/S)
        .00        1.01925           .000
       1.00        1.02430           .000
0  FROUDE NO= 53.07,  PORT SPACING/PORT DIA=     16.04,
+                                                    STARTING LENGTH=     .019

   ALL LENGTHS ARE IN METERS-TIME IN SEC.  FIRST LINE ARE INITIAL CONDITIONS.
     X        Y        Z      TH1      TH2     WIDTH     DUCL     DRHO     DCCL      TIME   DILUTION

     .00     .00      .00   90.00      .00     0.00    1.000    1.000    1.000       .00      1.00
    0.00     .02     0.00   90.00      .17      .01    1.000    1.000    1.000       .01      1.93
    0.00     .04     0.00   90.00      .83      .03     .312     .311     .311       .05      6.18
    0.00     .07     0.00   90.00     2.19      .05     .187     .186     .187       .12     10.32

   PLUMES MERGING

    0.00     .09     0.00   90.00     4.16      .06     .141     .140     .141       .23     13.68
    0.00     .12     0.00   90.00     6.53      .07     .120     .117     .119       .37     15.94
    0.00     .15      .01   90.00     9.16      .08     .103     .099     .101       .52     17.80
    0.00     .17      .01   90.00    11.94      .09     .089     .083     .087       .71     19.37
    0.00     .20      .02   90.00    14.79      .10     .078     .070     .075       .92     20.71
    0.00     .22      .03   90.00    17.61      .11     .073     .063     .070      1.15     21.90
    0.00     .24      .03   90.00    20.33      .12     .066     .054     .062      1.40     22.98
    0.00     .27      .04   90.00    22.92      .13     .065     .049     .059      1.67     24.00
    0.00     .31      .07   90.00    27.50      .15     .062     .039     .055      2.22     25.95
    0.00     .36      .09   90.00    31.19      .16     .060     .029     .051      2.80     27.83
    0.00     .40      .12   90.00    33.89      .18     .058     .019     .048      3.39     29.64
    0.00     .44      .15   90.00    35.60      .20     .056     .010     .045      4.00     31.38
    0.00     .48      .18   90.00    36.25      .22     .053     .001     .043      4.64     33.05

   PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

    0.00     .51      .20   90.00    36.07      .23     .052    -.005     .042      5.05     34.05
    0.00     .53      .21   90.00    35.56      .24     .050    -.009     .041      5.39     34.83
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      0.00     .59     .25   90.00   31.68      .28     .045    -.021     .039     6.48    37.01
      0.00     .61     .27   90.00   29.39      .30     .043    -.024     .038     6.88    37.69
      0.00     .64     .28   90.00   26.46      .32     .042    -.027     .037     7.29    38.33
      0.00     .66     .29   90.00   22.78      .34     .040    -.030     .037     7.71    38.95
      0.00     .68     .30   90.00   18.29      .36     .038    -.032     .036     8.16    39.54
      0.00     .71     .30   90.00   12.95      .38     .036    -.034     .036     8.63    40.10
      0.00     .73     .31   90.00    6.87      .40     .035    -.035     .035     9.12    40.64
      0.00     .76     .31   90.00     .29      .41     .035    -.035     .035     9.62    41.17

     PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT

     TRAPPING LEVEL=    .82 METERS BELOW SURFACE,  DILUTION=  33.17
1
   UNIVERSAL DATA FILE: DIFFUSER2.DAT

   #11 Simulation of Wright, et al diffuser data, Run 5-13-A
   0 1 0 0 0 0 0
  0.0001130        10  .00953   0.        1.
      0.   90.       0.051
         2    1.0000        0.
       00.00 1.005505    0.0
     1.00   1.00990     0.0
1
                                     PROGRAM UDKHDEN
                        SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
                        AMBIENT CURRENTS AND VERTICAL GRADIENTS.   AUG 1985

     UNIVERSAL DATA FILE: DIFFUSER2.DAT
     CASE I.D.  #11 Simulation of Wright, et al diffuser data, Run 5-13-A
     DISCHARGE=  .0001 CU-M/S  DENSITY=1.00000 G/CM3  ** DIAMETER=  .0095-M
     ** NUMBER OF PORTS=  10  ** SPACING=    .05-M  ** DEPTH=   1.00-M
0           AMBIENT STRATIFICATION PROFILE
      DEPTH (M)    DENSITY (G/CM3)   VELOCITY (M/S)
           .00        1.00550            .000
          1.00        1.00990            .000
0    FROUDE NO=  5.21,  PORT SPACING/PORT DIA=      5.35,
+                                                          STARTING LENGTH=     .056

     ALL LENGTHS ARE IN METERS-TIME IN SEC.  FIRST LINE ARE INITIAL CONDITIONS.
       X       Y       Z      TH1      TH2     WIDTH     DUCL     DRHO     DCCL      TIME   DILUTION

      .00     .00     .00   90.00     .00      .01    1.000    1.000    1.000       .00     1.00
     0.00     .06     .01   90.00   16.95      .03    1.000     .952     .955       .36     2.01

     PLUMES MERGING

     0.00     .12     .05   90.00   50.63      .06     .514     .298     .326      1.15     5.89
     0.00     .16     .12   90.00   64.80      .08     .494     .147     .211      2.10     8.76
     0.00     .19     .19   90.00   69.95      .10     .418     .055     .144      3.14    11.28

     PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

     0.00     .21     .26   90.00   71.35      .13     .335    -.001     .107      4.44    13.27
     0.00     .24     .33   90.00   69.15      .17     .268    -.044     .096      6.02    14.89
     0.00     .27     .40   90.00   47.63      .36     .132    -.083     .089      8.41    16.01
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    TRAPPING LEVEL=    .74 METERS BELOW SURFACE,  DILUTION=  13.21
1
  UNIVERSAL DATA FILE: DIFFUSER2.DAT

  #12 Simulation of Wright, et al diffuser data,Run 5-13-B
  0 1 0 0 0 0 0
 0.0001610        10  .00953   0.         1.
      0.     90.       0.102
         2    1.0000        0.
     00.00 1.003895    0.0
    1.00   1.00930     0.0
1
                                          PROGRAM UDKHDEN
                           SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
                           AMBIENT CURRENTS AND VERTICAL GRADIENTS.   AUG 1985

    UNIVERSAL DATA FILE: DIFFUSER2.DAT
    CASE I.D.  #12 Simulation of Wright, et al diffuser data,Run 5-13-B
    DISCHARGE=  .0002 CU-M/S  DENSITY=1.00000 G/CM3  ** DIAMETER=  .0095-M
    ** NUMBER OF PORTS=  10  ** SPACING=    .10-M  ** DEPTH=   1.00-M
0          AMBIENT STRATIFICATION PROFILE
     DEPTH (M)    DENSITY (G/CM3)   VELOCITY (M/S)
          .00        1.00389            .000
         1.00        1.00930            .000
0   FROUDE NO=  7.66,  PORT SPACING/PORT DIA=     10.70,
+                                                          STARTING LENGTH=     .056

    ALL LENGTHS ARE IN METERS-TIME IN SEC.  FIRST LINE ARE INITIAL CONDITIONS.
      X       Y       Z       TH1      TH2     WIDTH      DUCL      DRHO      DCCL       TIME    DILUTION

      .00     .00     .00    90.00      .00      .01     1.000     1.000     1.000        .00      1.00
     0.00     .06    0.00    90.00     7.91      .03     1.000      .987      .990        .25      1.94
     0.00     .13     .03    90.00    32.85      .08      .364      .285      .306        .90      6.29

    PLUMES MERGING

     0.00     .18     .08    90.00    52.88      .11      .295      .118      .178       1.96     10.78
     0.00     .22     .15    90.00    59.99      .14      .269      .026      .135       3.16     14.19

    PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

     0.00     .26     .21    90.00    58.19      .17      .198     -.043      .105       4.60     16.91
     0.00     .31     .27    90.00    20.44      .34      .082     -.075      .077       7.26     18.48

    PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT

    TRAPPING LEVEL=    .83 METERS BELOW SURFACE,  DILUTION=  15.27
1
  UNIVERSAL DATA FILE: DIFFUSER2.DAT

  #13 Simulation of Wright, et al diffuser data, Run 5-13-C
  0 1 0 0 0 0 0
 0.0000763        10  .00953   0.         1.
      0.     90.       0.051
         2    1.0000        0
```

```
   1.00   1.00950     0.
1
                                                  PROGRAM UDKHDEN
                               SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
                               AMBIENT CURRENTS AND VERTICAL GRADIENTS.   AUG 1985

    UNIVERSAL DATA FILE: DIFFUSER2.DAT
    CASE I.D.  #13 Simulation of Wright, et al diffuser data, Run 5-13-C
    DISCHARGE=  .0001 CU-M/S  DENSITY=1.00000 G/CM3  ** DIAMETER=  .0095-M
    ** NUMBER OF PORTS=  10  ** SPACING=    .05-M  ** DEPTH=   1.00-M
0          AMBIENT STRATIFICATION PROFILE
     DEPTH (M)    DENSITY (G/CM3)   VELOCITY (M/S)
          .00        1.00575            .000
         1.00        1.00950            .000
0   FROUDE NO=  3.59,  PORT SPACING/PORT DIA=      5.35,
+                                                              STARTING LENGTH=     .052

    ALL LENGTHS ARE IN METERS-TIME IN SEC.  FIRST LINE ARE INITIAL CONDITIONS.
      X        Y        Z       TH1      TH2     WIDTH     DUCL      DRHO      DCCL       TIME   DILUTION

      .00      .00      .00   90.00      .00      .01    1.000     1.000     1.000        .00     1.00
     0.00      .05      .01   90.00    32.36      .03    1.000      .837      .843        .52     2.28

    PLUMES MERGING

     0.00      .10      .07   90.00    65.57      .06     .667      .243      .276       1.49     6.95
     0.00      .12      .15   90.00    74.39      .08     .641      .108      .173       2.57    10.75
     0.00      .14      .22   90.00    77.24      .10     .525      .030      .116       3.78    13.98

    PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

     0.00      .16      .28   90.00    77.56      .13     .407     -.012      .088       5.13    16.16
     0.00      .17      .35   90.00    75.12      .18     .309     -.045      .080       6.86    17.85
     0.00      .20      .41   90.00    14.16      .69     .076     -.076      .075      10.17    18.90

    PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT

    TRAPPING LEVEL=    .74 METERS BELOW SURFACE,  DILUTION=  15.53
1
  UNIVERSAL DATA FILE: DIFFUSER2.DAT

  #14 Simulation of Wright, et al diffuser data, Run 5-13-D
   0 1 0 0 0 0 0
  0.0002540         10  .00953   0.        1.
       0.      90.       0.152
          2    1.0000         0.
       00.00 1.00487    0.0
    1.00   1.00950     0.
1
                                                  PROGRAM UDKHDEN
                               SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
                               AMBIENT CURRENTS AND VERTICAL GRADIENTS.   AUG 1985

    UNIVERSAL DATA FILE: DIFFUSER2.DAT
    CASE I.D.  #14 Simulation of Wright, et al diffuser data, Run 5-13-D
    DISCHARGE=  .0003 CU-M/S  DENSITY=1.00000 G/CM3  ** DIAMETER=  .0095-M
```

```
0          AMBIENT STRATIFICATION PROFILE
     DEPTH (M)    DENSITY (G/CM3)   VELOCITY (M/S)
          .00        1.00487           .000
         1.00        1.00950           .000
0   FROUDE NO= 11.95,  PORT SPACING/PORT DIA=     15.95,
+                                                                   STARTING LENGTH=     .056

    ALL LENGTHS ARE IN METERS-TIME IN SEC.  FIRST LINE ARE INITIAL CONDITIONS.
      X        Y        Z       TH1      TH2      WIDTH     DUCL      DRHO      DCCL       TIME   DILUTION

     .00      .00      .00    90.00      .00       .01     1.000     1.000     1.000       .00     1.00
    0.00      .06     0.00    90.00     3.25       .03     1.000      .997      .998       .16     1.93
    0.00      .13      .01    90.00    15.69       .08      .322      .302      .310       .59     6.21
    0.00      .20      .04    90.00    33.83       .13      .219      .153      .182      1.43    10.57

    PLUMES MERGING

    0.00      .26      .09    90.00    46.37       .17      .187      .068      .129      2.50    14.90
    0.00      .31      .15    90.00    50.93       .20      .167      .006      .106      3.71    18.13

    PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

    0.00      .36      .21    90.00    47.00       .24      .130     -.044      .089      5.14    20.72
    0.00      .42      .25    90.00    17.81       .35      .067     -.062      .064      7.40    22.39

    PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT

    TRAPPING LEVEL=    .84 METERS BELOW SURFACE,  DILUTION=  18.48
```

```
1
  UNIVERSAL DATA FILE: DIFFUSER3.DAT

   #15 Simulation of Wright, et al diffuser data, Run 5-14-A
   0 1 0 0 0 0 0
  0.0001710        10  .00953   0.         1.
         0.    90.       0.051
           2    1.0000         0.
       00.00 1.000739    0.0
     1.00   1.00490     0.
1
                                          PROGRAM UDKHDEN
                            SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
                            AMBIENT CURRENTS AND VERTICAL GRADIENTS.   AUG 1985

    UNIVERSAL DATA FILE: DIFFUSER3.DAT
    CASE I.D.  #15 Simulation of Wright, et al diffuser data, Run 5-14-A
    DISCHARGE=  .0002 CU-M/S  DENSITY=1.00000 G/CM3  ** DIAMETER=  .0095-M
    ** NUMBER OF PORTS=  10  ** SPACING=    .05-M  ** DEPTH=   1.00-M
0          AMBIENT STRATIFICATION PROFILE
     DEPTH (M)    DENSITY (G/CM3)   VELOCITY (M/S)
          .00        1.00074           .000
         1.00        1.00490           .000
0   FROUDE NO= 11.21,  PORT SPACING/PORT DIA=      5.35,
+                                                          STARTING LENGTH=     .057

    ALL LENGTHS ARE IN METERS-TIME IN SEC.  FIRST LINE ARE INITIAL CONDITIONS.
      X       Y        Z       TH1      TH2     WIDTH     DUCL      DRHO      DCCL       TIME    DILUTION

      .00     .00      .00    90.00     .00      .01     1.000     1.000     1.000       .00     1.00
     0.00     .06     0.00    90.00    3.79      .03     1.000      .996      .997       .24     1.93

    PLUMES MERGING

     0.00     .13      .01    90.00   16.57      .07      .375      .343      .359       .85     5.30
     0.00     .20      .05    90.00   31.71      .09      .280      .187      .238      1.89     7.11
     0.00     .26      .09    90.00   41.16      .12      .223      .080      .168      3.23     8.48
     0.00     .32      .14    90.00   44.75      .15      .208      .010      .148      4.70     9.64

    PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

     0.00     .37      .20    90.00   42.49      .18      .181     -.052      .134      6.33    10.66
     0.00     .43      .24    90.00   29.50      .25      .142     -.102      .124      8.29    11.51
     0.00     .51      .26    90.00   -6.95      .32      .118     -.116      .117     10.82    12.16

    PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT

    TRAPPING LEVEL=    .85 METERS BELOW SURFACE,  DILUTION=   9.81
1
  UNIVERSAL DATA FILE: DIFFUSER3.DAT

  #16 Simulation of Wright, et al diffuser data,Run 5-14-C
  0 1 0 0 0 0 0
 0.0000509        10  .00318   0.         1.
        0.    90.       0.152
          2    1.0000         0
```

```
    1.00   1.00480    0.0
1
                                  PROGRAM UDKHDEN
                      SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
                      AMBIENT CURRENTS AND VERTICAL GRADIENTS.   AUG 1985

    UNIVERSAL DATA FILE: DIFFUSER3.DAT
    CASE I.D.  #16 Simulation of Wright, et al diffuser data,Run 5-14-C
    DISCHARGE=  .0001 CU-M/S  DENSITY=1.00000 G/CM3  ** DIAMETER=  .0032-M
    ** NUMBER OF PORTS=  10  ** SPACING=    .15-M  ** DEPTH=   1.00-M
0          AMBIENT STRATIFICATION PROFILE
     DEPTH (M)    DENSITY (G/CM3)   VELOCITY (M/S)
         .00        1.00129           .000
        1.00        1.00490           .000
0   FROUDE NO= 51.86,  PORT SPACING/PORT DIA=     47.80,
+                                                             STARTING LENGTH=     .018

    ALL LENGTHS ARE IN METERS-TIME IN SEC.  FIRST LINE ARE INITIAL CONDITIONS.
      X        Y        Z       TH1      TH2      WIDTH      DUCL      DRHO      DCCL       TIME    DILUTION

      .00      .00      .00    90.00      .00     0.00     1.000     1.000     1.000        .00      1.00
     0.00      .02     0.00    90.00      .17      .01     1.000     1.000     1.000        .03      1.93
     0.00      .04     0.00    90.00      .88      .03      .308      .307      .307        .11      6.26
     0.00      .07     0.00    90.00     2.32      .05      .183      .181      .182        .28     10.56
     0.00      .09     0.00    90.00     4.46      .07      .130      .128      .130        .54     14.81
     0.00      .12     0.00    90.00     7.23      .09      .102      .096      .101        .89     19.03
     0.00      .15      .01    90.00    10.45      .10      .084      .074      .083       1.32     23.22
     0.00      .17      .01    90.00    13.86      .12      .072      .055      .070       1.83     27.39
     0.00      .19      .02    90.00    17.10      .14      .064      .039      .061       2.42     31.55

    PLUMES MERGING

     0.00      .22      .03    90.00    19.77      .16      .057      .024      .054       3.07     35.65
     0.00      .24      .04    90.00    21.44      .17      .053      .009      .050       3.79     38.90

    PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

     0.00      .27      .05    90.00    21.72      .18      .050     -.004      .046       4.57     41.71
     0.00      .29      .06    90.00    20.32      .19      .046     -.016      .043       5.39     44.23
     0.00      .31      .06    90.00    16.88      .21      .043     -.027      .041       6.28     46.52
     0.00      .34      .07    90.00    11.18      .22      .040     -.034      .039       7.25     48.59
     0.00      .36      .07    90.00     3.42      .23      .037     -.036      .037       8.29     50.48

    PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT

    TRAPPING LEVEL=    .96 METERS BELOW SURFACE,  DILUTION=  40.87
1
  UNIVERSAL DATA FILE: DIFFUSER3.DAT

  #17 Simulation of Wright, et al diffuser data, Run 5-14-D
  0 1 0 0 0 0 0
 0.0000295         10  .00318   0.          1.
      0.     90.       0.051
         2   1.0000         0.
     00.00 1.001516     0.0
    1.00   1.00480      0.0
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                                   PROGRAM UDKHDEN
                        SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
                        AMBIENT CURRENTS AND VERTICAL GRADIENTS.   AUG 1985

    UNIVERSAL DATA FILE: DIFFUSER3.DAT
    CASE I.D.  #17 Simulation of Wright, et al diffuser data, Run 5-14-D
    DISCHARGE= 0.0000 CU-M/S  DENSITY=1.00000 G/CM3  ** DIAMETER=  .0032-M
    ** NUMBER OF PORTS=  10  ** SPACING=     .05-M  ** DEPTH=   1.00-M
0           AMBIENT STRATIFICATION PROFILE
     DEPTH (M)     DENSITY (G/CM3)   VELOCITY (M/S)
         .00         1.00152            .000
        1.00         1.00480            .000
0   FROUDE NO= 30.37,  PORT SPACING/PORT DIA=      16.04,
+                                                            STARTING LENGTH=     .019

    ALL LENGTHS ARE IN METERS-TIME IN SEC.  FIRST LINE ARE INITIAL CONDITIONS.
       X        Y        Z       TH1      TH2     WIDTH      DUCL      DRHO      DCCL       TIME    DILUTION

      .00      .00      .00     90.00      .00     0.00     1.000     1.000     1.000        .00      1.00
     0.00      .02     0.00     90.00      .50      .01     1.000     1.000     1.000        .05      1.93
     0.00      .04     0.00     90.00     2.54      .03      .312      .311      .311        .19      6.18
     0.00      .07     0.00     90.00     6.61      .05      .188      .184      .187        .48     10.32

    PLUMES MERGING

     0.00      .09      .01     90.00    12.29      .06      .143      .133      .140        .91     13.78
     0.00      .12      .01     90.00    18.42      .07      .124      .104      .118       1.43     16.10
     0.00      .14      .02     90.00    24.13      .08      .111      .079      .102       2.01     18.06
     0.00      .17      .03     90.00    28.87      .09      .100      .055      .088       2.66     19.80
     0.00      .19      .05     90.00    32.36      .10      .091      .034      .077       3.37     21.35
     0.00      .21      .06     90.00    34.52      .10      .082      .016      .068       4.17     22.73

    PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

     0.00      .23      .08     90.00    35.25      .12      .073     0.000      .059       5.03     24.00
     0.00      .25      .09     90.00    34.40      .13      .069     -.014      .057       6.00     25.11
     0.00      .27      .10     90.00    31.61      .14      .064     -.027      .055       7.03     26.15
     0.00      .29      .12     90.00    26.23      .16      .059     -.038      .053       8.15     27.10
     0.00      .32      .13     90.00    17.35      .18      .053     -.046      .051       9.37     27.96
     0.00      .34      .13     90.00     4.70      .20      .050     -.049      .050      10.70     28.75

    PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT

    TRAPPING LEVEL=    .92 METERS BELOW SURFACE,  DILUTION=  23.98
1
  UNIVERSAL DATA FILE: DIFFUSER3.DAT

  #18 Simulation of Wright, et al diffuser data, Run 5-15-A
  0 1 0 0 0 0 0
 0.0000715         10  .00318   0.         1.
      0.    90.     0.102
         2    1.0000        0.
     00.00 1.005559    0.0
    1.00   1.00920     0.0
1
                                   PROGRAM UDKHDEN
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                     AMBIENT CURRENTS AND VERTICAL GRADIENTS.   AUG 1985

    UNIVERSAL DATA FILE: DIFFUSER3.DAT
    CASE I.D.  #18 Simulation of Wright, et al diffuser data, Run 5-15-A
    DISCHARGE=  .0001 CU-M/S  DENSITY=1.00000 G/CM3  ** DIAMETER=  .0032-M
    ** NUMBER OF PORTS=  10  ** SPACING=    .10-M  ** DEPTH=   1.00-M
0           AMBIENT STRATIFICATION PROFILE
     DEPTH (M)     DENSITY (G/CM3)   VELOCITY (M/S)
          .00         1.00556            .000
         1.00         1.00920            .000
0   FROUDE NO= 53.17,  PORT SPACING/PORT DIA=     32.08,
+                                                       STARTING LENGTH=     .019

    ALL LENGTHS ARE IN METERS-TIME IN SEC.  FIRST LINE ARE INITIAL CONDITIONS.
       X        Y        Z      TH1      TH2     WIDTH     DUCL      DRHO     DCCL       TIME   DILUTION

      .00      .00      .00    90.00      .00     0.00     1.000     1.000    1.000       .00      1.00
     0.00      .02     0.00    90.00      .16      .01     1.000     1.000    1.000       .02      1.93
     0.00      .04     0.00    90.00      .83      .03      .308      .308     .308       .08      6.24
     0.00      .07     0.00    90.00     2.20      .05      .184      .183     .183       .20     10.50
     0.00      .09     0.00    90.00     4.24      .07      .131      .130     .131       .39     14.69
     0.00      .12     0.00    90.00     6.89      .08      .103      .100     .102       .63     18.83

    PLUMES MERGING

     0.00      .15      .01    90.00    10.06      .10      .085      .079     .084       .93     22.91
     0.00      .17      .01    90.00    13.51      .12      .076      .066     .074      1.29     26.13
     0.00      .19      .02    90.00    16.95      .13      .070      .055     .067      1.68     28.75
     0.00      .22      .03    90.00    20.16      .14      .066      .044     .062      2.09     31.09
     0.00      .24      .04    90.00    22.96      .14      .062      .034     .057      2.54     33.25
     0.00      .27      .05    90.00    25.22      .15      .058      .024     .053      3.01     35.25
     0.00      .31      .07    90.00    27.78      .17      .051      .006     .045      4.04     38.86

    PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

     0.00      .34      .09    90.00    27.68      .19      .046     -.006     .040      4.92     41.21
     0.00      .37      .10    90.00    26.46      .20      .041     -.013     .037      5.57     42.60
     0.00      .39      .11    90.00    24.16      .21      .038     -.019     .035      6.28     43.86
     0.00      .41      .12    90.00    20.60      .24      .034     -.022     .032      7.06     45.02
     0.00      .44      .13    90.00    15.65      .25      .032     -.026     .031      7.92     46.05
     0.00      .46      .13    90.00     9.29      .27      .031     -.029     .030      8.82     47.03
     0.00      .49      .14    90.00     1.85      .28      .030     -.030     .030      9.75     47.96

    PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT

    TRAPPING LEVEL=     .92 METERS BELOW SURFACE,  DILUTION=  39.96
1
  UNIVERSAL DATA FILE: DIFFUSER3.DAT

  #19 Simulation of Wright, et al diffuser data,Run 5-15-B
  0 1 0 0 0 0 0
 0.0000889        10  .00318   0.         1.
      0.     90.       0.203
         2    1.0000         0.
     00.00 1.003938    0.0
    1.00   1.00870     0.0
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                              PROGRAM UDKHDEN
                  SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
                  AMBIENT CURRENTS AND VERTICAL GRADIENTS.   AUG 1985

   UNIVERSAL DATA FILE: DIFFUSER3.DAT
   CASE I.D.  #19 Simulation of Wright, et al diffuser data,Run 5-15-B
   DISCHARGE=  .0001 CU-M/S  DENSITY=1.00000 G/CM3  ** DIAMETER=  .0032-M
   ** NUMBER OF PORTS=  10  ** SPACING=    .20-M  ** DEPTH=   1.00-M
0          AMBIENT STRATIFICATION PROFILE
    DEPTH (M)    DENSITY (G/CM3)   VELOCITY (M/S)
        .00        1.00394           .000
       1.00        1.00870           .000
0  FROUDE NO= 67.98,  PORT SPACING/PORT DIA=     63.84,
+                                                     STARTING LENGTH=     .018

   ALL LENGTHS ARE IN METERS-TIME IN SEC.  FIRST LINE ARE INITIAL CONDITIONS.
     X       Y        Z       TH1      TH2      WIDTH     DUCL      DRHO      DCCL      TIME    DILUTION

     .00     .00     .00    90.00      .00      0.00     1.000     1.000     1.000      .00      1.00
    0.00     .02    0.00    90.00      .10       .01     1.000     1.000     1.000      .02      1.93
    0.00     .04    0.00    90.00      .51       .03      .307      .307      .307      .06      6.27
    0.00     .07    0.00    90.00     1.35       .05      .182      .181      .182      .16     10.59
    0.00     .09    0.00    90.00     2.62       .07      .130      .128      .129      .31     14.87
    0.00     .12    0.00    90.00     4.29       .09      .101      .098      .101      .51     19.13
    0.00     .15     .01    90.00     6.31       .11      .083      .078      .082      .76     23.35
    0.00     .17     .01    90.00     8.61       .12      .071      .063      .070     1.06     27.55
    0.00     .20     .01    90.00    11.08       .14      .062      .051      .061     1.40     31.74
    0.00     .22     .02    90.00    13.56       .16      .055      .039      .054     1.79     35.90
    0.00     .25     .02    90.00    15.85       .18      .050      .029      .048     2.23     40.06
    0.00     .27     .03    90.00    17.75       .20      .046      .019      .044     2.70     44.21

   PLUMES MERGING


   PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

    0.00     .32     .05    90.00    19.50       .23      .040     0.000      .038     3.78     51.33
    0.00     .34     .06    90.00    18.93       .24      .038     -.009      .036     4.36     54.17
    0.00     .37     .06    90.00    17.17       .25      .035     -.017      .034     4.99     56.77
    0.00     .39     .07    90.00    14.07       .26      .033     -.023      .032     5.65     59.16
    0.00     .42     .08    90.00     9.57       .28      .032     -.027      .031     6.35     61.37
    0.00     .44     .08    90.00     3.86       .29      .030     -.029      .030     7.09     63.43

   PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT

   TRAPPING LEVEL=    .95 METERS BELOW SURFACE,  DILUTION=  51.25
1
  UNIVERSAL DATA FILE: DIFFUSER3.DAT

  #20 Simulation of Wright, et al diffuser data, Run 5-15-C
  0 1 0 0 0 0 0
 0.0000320        10  .00318   0.        1.
      0.     90.       0.051
         2    1.0000         0.
     00.00 1.004211    0.0
   1.00   1.00880      0
```

```
                                      PROGRAM UDKHDEN
                         SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
                         AMBIENT CURRENTS AND VERTICAL GRADIENTS.   AUG 1985

    UNIVERSAL DATA FILE: DIFFUSER3.DAT
    CASE I.D.  #20 Simulation of Wright, et al diffuser data, Run 5-15-C
    DISCHARGE= 0.0000 CU-M/S  DENSITY=1.00000 G/CM3  ** DIAMETER=  .0032-M
    ** NUMBER OF PORTS=  10  ** SPACING=    .05-M  ** DEPTH=   1.00-M
0          AMBIENT STRATIFICATION PROFILE
     DEPTH (M)    DENSITY (G/CM3)   VELOCITY (M/S)
          .00         1.00421            .000
         1.00         1.00880            .000
0   FROUDE NO= 24.33,  PORT SPACING/PORT DIA=     16.04,
+                                                          STARTING LENGTH=     .019

    ALL LENGTHS ARE IN METERS-TIME IN SEC.  FIRST LINE ARE INITIAL CONDITIONS.
       X        Y        Z       TH1      TH2      WIDTH      DUCL      DRHO      DCCL       TIME   DILUTION

      .00      .00      .00    90.00      .00      0.00     1.000     1.000     1.000        .00     1.00
     0.00      .02     0.00    90.00      .79       .01     1.000     1.000     1.000        .05     1.93
     0.00      .04     0.00    90.00     3.95       .03      .312      .311      .311        .18     6.18
     0.00      .07     0.00    90.00    10.20       .05      .189      .183      .186        .44    10.33

    PLUMES MERGING

     0.00      .09      .01    90.00    18.55       .06      .147      .131      .139        .83    13.85
     0.00      .12      .02    90.00    26.85       .07      .131      .101      .117       1.29    16.27
     0.00      .14      .03    90.00    33.83       .08      .122      .076      .101       1.79    18.39
     0.00      .16      .05    90.00    39.08       .08      .113      .052      .088       2.33    20.33
     0.00      .18      .06    90.00    42.67       .09      .105      .032      .077       2.90    22.11
     0.00      .20      .08    90.00    44.73       .10      .094      .013      .067       3.54    23.72

    PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

     0.00      .22      .10    90.00    45.30       .11      .087     -.002      .061       4.24    25.16
     0.00      .23      .12    90.00    44.22       .12      .075     -.015      .054       5.03    26.44
     0.00      .25      .14    90.00    40.92       .14      .068     -.027      .052       5.91    27.56
     0.00      .27      .15    90.00    34.09       .17      .060     -.037      .050       6.89    28.56
     0.00      .29      .16    90.00    21.10       .20      .052     -.045      .048       8.02    29.43
     0.00      .32      .17    90.00      .10       .22      .047     -.047      .047       9.31    30.19

    PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT

    TRAPPING LEVEL=    .90 METERS BELOW SURFACE,  DILUTION=  24.98
1
  UNIVERSAL DATA FILE: DIFFUSER3.DAT

  #21 Simulation of Wright, et al diffuser data, Run 5-15-D
  0 1 0 0 0 0 0
 0.0000401        10  .00318   0.        1.
      0.     90.       0.102
         2   1.0000       0.
      00.00 1.006032    0.0
    1.00   1.00900     0.
1
                                      PROGRAM UDKHDEN
```

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                      AMBIENT CURRENTS AND VERTICAL GRADIENTS.   AUG 1985

    UNIVERSAL DATA FILE: DIFFUSER3.DAT
    CASE I.D.  #21 Simulation of Wright, et al diffuser data, Run 5-15-D
    DISCHARGE= 0.0000 CU-M/S  DENSITY=1.00000 G/CM3  ** DIAMETER=  .0032-M
    ** NUMBER OF PORTS=  10  ** SPACING=    .10-M  ** DEPTH=   1.00-M
0          AMBIENT STRATIFICATION PROFILE
     DEPTH (M)    DENSITY (G/CM3)   VELOCITY (M/S)
         .00        1.00603            .000
        1.00        1.00900            .000
0   FROUDE NO= 30.15,  PORT SPACING/PORT DIA=     32.08,
+                                                      STARTING LENGTH=     .019

    ALL LENGTHS ARE IN METERS-TIME IN SEC.  FIRST LINE ARE INITIAL CONDITIONS.
      X        Y        Z      TH1     TH2     WIDTH     DUCL     DRHO     DCCL      TIME   DILUTION

      .00      .00      .00   90.00     .00     0.00    1.000    1.000    1.000       .00     1.00
     0.00      .02     0.00   90.00     .51      .01    1.000    1.000    1.000       .04     1.93
     0.00      .04     0.00   90.00    2.59      .03     .309     .308     .308       .14     6.24
     0.00      .07     0.00   90.00    6.79      .05     .185     .182     .183       .36    10.51
     0.00      .09      .01   90.00   12.83      .07     .134     .128     .131       .68    14.73
     0.00      .12      .01   90.00   20.04      .08     .108     .095     .102      1.11    18.94
     0.00      .14      .02   90.00   27.43      .10     .093     .072     .083      1.61    23.20

    PLUMES MERGING

     0.00      .16      .04   90.00   34.01      .11     .086     .054     .071      2.18    27.01
     0.00      .18      .05   90.00   39.14      .12     .082     .039     .064      2.78    30.14
     0.00      .20      .07   90.00   42.77      .13     .079     .025     .058      3.40    33.01
     0.00      .22      .09   90.00   44.97      .14     .076     .013     .054      4.05    35.69
     0.00      .24      .11   90.00   45.79      .15     .071     .001     .050      4.74    38.19

    PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

     0.00      .26      .13   90.00   44.63      .16     .063    -.013     .045      5.68    40.98
     0.00      .28      .15   90.00   41.28      .18     .054    -.021     .040      6.54    42.90
     0.00      .30      .16   90.00   34.37      .20     .043    -.026     .035      7.59    44.48
     0.00      .32      .17   90.00   21.20      .24     .033    -.029     .031      8.92    45.71
     0.00      .35      .18   90.00    -.08      .27     .030    -.031     .031     10.52    46.70

    PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT

    TRAPPING LEVEL=    .89 METERS BELOW SURFACE,  DILUTION=  38.35
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```
1
  UNIVERSAL DATA FILE: DIFFUSER4.DAT

  #22 Simulation of Wright, et al diffuser data, Run 5-16-B
  0 1 0 0 0 0 0
 0.0000806        10  .00953   0.        1.
       0.     90.       0.051
         2    1.0000        0.
      00.00 1.014077    0.0
    1.00   1.02350     0.
1
                                         PROGRAM UDKHDEN
                         SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
                         AMBIENT CURRENTS AND VERTICAL GRADIENTS.   AUG 1985

    UNIVERSAL DATA FILE: DIFFUSER4.DAT
    CASE I.D.  #22 Simulation of Wright, et al diffuser data, Run 5-16-B
    DISCHARGE=  .0001 CU-M/S  DENSITY=1.00000 G/CM3  ** DIAMETER=  .0095-M
    ** NUMBER OF PORTS=  10  ** SPACING=    .05-M  ** DEPTH=   1.00-M
0          AMBIENT STRATIFICATION PROFILE
     DEPTH (M)    DENSITY (G/CM3)   VELOCITY (M/S)
          .00        1.01408           .000
         1.00        1.02350           .000

   ***********************************************
   * THIS RUN DISCONTINUED, BECAUSE THE INITIAL  *
   * FROUDE NUMBER (2.41) IS LESS THAN 2.44, AND *
   * THE MODEL WILL NOT RUN CORRECTLY.           *
   ***********************************************

1
  UNIVERSAL DATA FILE: DIFFUSER4.DAT

  #23 Simulation of Wright, et al diffuser data,Run 6-4-A
  0 1 0 0 0 0 0
 0.0003290        10  .00953   0.        1.
       0.     90.       0.102
         2    1.0000        0.
      00.00 1.009793   0.0
    1.00   1.01580    0.0
1
                                         PROGRAM UDKHDEN
                         SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
                         AMBIENT CURRENTS AND VERTICAL GRADIENTS.   AUG 1985

    UNIVERSAL DATA FILE: DIFFUSER4.DAT
    CASE I.D.  #23 Simulation of Wright, et al diffuser data,Run 6-4-A
    DISCHARGE=  .0003 CU-M/S  DENSITY=1.00000 G/CM3  ** DIAMETER=  .0095-M
    ** NUMBER OF PORTS=  10  ** SPACING=    .10-M  ** DEPTH=   1.00-M
0          AMBIENT STRATIFICATION PROFILE
     DEPTH (M)    DENSITY (G/CM3)   VELOCITY (M/S)
          .00        1.00979           .000
         1.00        1.01580           .000
0   FROUDE NO= 12.01,  PORT SPACING/PORT DIA=     10.70,
+                                                    STARTING LENGTH=     .056
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```
          X          Y          Z        TH1       TH2       WIDTH       DUCL       DRHO       DCCL        TIME    DILUTION

         .00        .00        .00     90.00       .00         .01      1.000      1.000      1.000         .00       1.00
        0.00        .06       0.00     90.00      3.24         .03      1.000       .998       .998         .12       1.93
        0.00        .13        .01     90.00     15.54         .08       .325       .307       .313         .46       6.15

      PLUMES MERGING

        0.00        .20        .04     90.00     33.50         .12       .234       .171       .195        1.08       9.87
        0.00        .26        .09     90.00     45.92         .14       .218       .101       .152        1.82      12.52
        0.00        .31        .15     90.00     52.25         .16       .199       .045       .122        2.60      14.88

      PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

        0.00        .35        .21     90.00     54.23         .19       .168      0.000       .098        3.50      16.91
        0.00        .40        .27     90.00     51.60         .24       .124      -.032       .077        4.63      18.51
        0.00        .45        .33     90.00     38.63         .33       .093      -.059       .072        6.15      19.67
        0.00        .52        .35     90.00    -10.11         .45       .071      -.069       .070        8.29      20.49

      PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT

      TRAPPING LEVEL=     .79 METERS BELOW SURFACE,  DILUTION=  16.89
1
    UNIVERSAL DATA FILE: DIFFUSER4.DAT

    #24 Simulation of Wright, et al diffuser data, Run 6-4-B
    0 1 0 0 0 0 0
   0.0005750          10  .00953   0.         1.
        0.      90.       0.152
           2    1.0000        0.
       00.00 1.011456     0.0
     1.00    1.01580      0.0
1
                                        PROGRAM UDKHDEN
                           SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
                           AMBIENT CURRENTS AND VERTICAL GRADIENTS.   AUG 1985

      UNIVERSAL DATA FILE: DIFFUSER4.DAT
      CASE I.D.  #24 Simulation of Wright, et al diffuser data, Run 6-4-B
      DISCHARGE=  .0006 CU-M/S  DENSITY=1.00000 G/CM3  ** DIAMETER=  .0095-M
      ** NUMBER OF PORTS=  10  ** SPACING=     .15-M  ** DEPTH=   1.00-M
0            AMBIENT STRATIFICATION PROFILE
       DEPTH (M)    DENSITY (G/CM3)   VELOCITY (M/S)
            .00         1.01146            .000
           1.00         1.01580            .000
0     FROUDE NO= 20.98,  PORT SPACING/PORT DIA=      15.95,
+                                                        STARTING LENGTH=     .056

      ALL LENGTHS ARE IN METERS-TIME IN SEC.  FIRST LINE ARE INITIAL CONDITIONS.
          X          Y          Z        TH1       TH2       WIDTH       DUCL       DRHO       DCCL        TIME    DILUTION

         .00        .00        .00     90.00       .00         .01      1.000      1.000      1.000         .00       1.00
        0.00        .06       0.00     90.00      1.06         .03      1.000      1.000      1.000         .07       1.93
        0.00        .13       0.00     90.00      5.30         .08       .313       .310       .311         .26       6.19
        0.00        .21        .02     90.00     13.47         .14       .191       .180       .186         .66      10.35
```

```
    0.00     .28     .04   90.00   23.60       .18      .151      .122      .138       1.23     13.91
    0.00     .35     .08   90.00   32.41       .20      .138      .085      .116       1.89     16.43
    0.00     .41     .12   90.00   38.60       .23      .128      .052      .100       2.60     18.66
    0.00     .47     .17   90.00   42.10       .25      .117      .022      .087       3.37     20.67

   PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

    0.00     .52     .22   90.00   42.97       .28      .102     -.004      .075       4.24     22.45
    0.00     .58     .27   90.00   40.75       .31      .085     -.025      .064       5.26     23.94
    0.00     .64     .32   90.00   33.74       .39      .068     -.040      .057       6.52     25.15
    0.00     .71     .35   90.00   17.83       .48      .057     -.051      .055       8.03     26.12
    0.00     .78     .36   90.00   -8.46       .53      .053     -.052      .053       9.77     26.96

   PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT

   TRAPPING LEVEL=    .79 METERS BELOW SURFACE,  DILUTION=  22.15
1
  UNIVERSAL DATA FILE: DIFFUSER4.DAT

  #25 Simulation of Wright, et al diffuser data, Run 6-10-B
  0 1 0 0 0 0 0
 0.0005570        10  .00953   0.        1.
      0.   90.       0.102
         2   1.0000        0.
     00.00 1.004570    0.0
   1.00   1.01280     0.0
1
                                    PROGRAM UDKHDEN
                        SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
                        AMBIENT CURRENTS AND VERTICAL GRADIENTS.   AUG 1985

   UNIVERSAL DATA FILE: DIFFUSER4.DAT
   CASE I.D.  #25 Simulation of Wright, et al diffuser data, Run 6-10-B
   DISCHARGE=  .0006 CU-M/S  DENSITY=1.00000 G/CM3  ** DIAMETER=  .0095-M
   ** NUMBER OF PORTS=  10  ** SPACING=    .10-M  ** DEPTH=   1.00-M
0          AMBIENT STRATIFICATION PROFILE
    DEPTH (M)    DENSITY (G/CM3)   VELOCITY (M/S)
         .00        1.00457            .000
        1.00        1.01280            .000
0  FROUDE NO= 22.58,  PORT SPACING/PORT DIA=     10.70,
+                                                         STARTING LENGTH=     .056

   ALL LENGTHS ARE IN METERS-TIME IN SEC.  FIRST LINE ARE INITIAL CONDITIONS.
      X       Y       Z      TH1     TH2     WIDTH     DUCL      DRHO      DCCL       TIME   DILUTION

     .00     .00     .00   90.00     .00       .01     1.000     1.000     1.000       .00      1.00
    0.00     .06    0.00   90.00     .92       .03     1.000      .999     1.000       .07      1.93
    0.00     .13    0.00   90.00    4.55       .08      .315      .311      .314       .27      6.13

   PLUMES MERGING

    0.00     .21     .01   90.00   11.35       .13      .204      .188      .200       .67      9.59
    0.00     .28     .03   90.00   18.87       .16      .166      .125      .157      1.20     11.71
    0.00     .35     .06   90.00   25.05       .18      .139      .071      .126      1.84     13.39
    0.00     .42     .10   90.00   28.74       .21      .119      .026      .104      2.60     14.78
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    PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

     0.00      .49      .13   90.00   29.35      .25      .103    -.011      .089      3.50    15.94
     0.00      .55      .17   90.00   26.15      .29      .094    -.042      .084      4.49    16.97
     0.00      .62      .20   90.00   17.78      .34      .084    -.066      .080      5.60    17.89
     0.00      .70      .21   90.00    3.40      .38      .076    -.076      .076      6.82    18.71

    PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT

    TRAPPING LEVEL=    .88 METERS BELOW SURFACE,  DILUTION=  15.60
1
  UNIVERSAL DATA FILE: DIFFUSER4.DAT

  #26 Simulation of Wright, et al diffuser data,Run 6-10-C
  0 1 0 0 0 0 0
 0.0008220         10  .00953   0.         1.
      0.     90.       0.152
         2    1.0000         0.
      00.00 1.00606    0.0
    1.00   1.01290     0.0
1
                                              PROGRAM UDKHDEN
                              SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
                              AMBIENT CURRENTS AND VERTICAL GRADIENTS.   AUG 1985

    UNIVERSAL DATA FILE: DIFFUSER4.DAT
    CASE I.D.  #26 Simulation of Wright, et al diffuser data,Run 6-10-C
    DISCHARGE=  .0008 CU-M/S  DENSITY=1.00000 G/CM3  ** DIAMETER=  .0095-M
    ** NUMBER OF PORTS=  10  ** SPACING=    .15-M  ** DEPTH=   1.00-M
0          AMBIENT STRATIFICATION PROFILE
     DEPTH (M)    DENSITY (G/CM3)   VELOCITY (M/S)
         .00        1.00606           .000
        1.00        1.01290           .000
0   FROUDE NO= 33.20,  PORT SPACING/PORT DIA=     15.95,
+                                                              STARTING LENGTH=     .056

    ALL LENGTHS ARE IN METERS-TIME IN SEC.  FIRST LINE ARE INITIAL CONDITIONS.
      X       Y       Z       TH1      TH2      WIDTH     DUCL      DRHO      DCCL       TIME   DILUTION

      .00     .00     .00   90.00      .00      .01     1.000     1.000     1.000       .00     1.00
     0.00     .06    0.00   90.00      .42      .03     1.000     1.000     1.000       .05     1.93
     0.00     .13    0.00   90.00     2.12      .08      .312      .310      .311       .19     6.18
     0.00     .21     .01   90.00     5.52      .14      .187      .182      .187       .47    10.32

    PLUMES MERGING

     0.00     .28     .02   90.00    10.17      .18      .143      .128      .141       .88    13.67
     0.00     .36     .03   90.00    15.03      .21      .123      .092      .119      1.38    15.97
     0.00     .43     .06   90.00    19.20      .24      .108      .058      .102      1.96    17.89
     0.00     .50     .08   90.00    22.02      .27      .094      .026      .087      2.61    19.54

    PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

     0.00     .57     .11   90.00    22.99      .30      .081     -.001      .075      3.36    20.95
     0.00     .64     .14   90.00    21.70      .32      .074     -.024      .069      4.22    22.18
     0.00     .71     .17   90.00    17.69      .39      .064     -.041      .061      5.20    23.24
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     0.00     .86     .19   90.00     .91      .47     .057    -.057     .057      7.40    25.10

    PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT

    TRAPPING LEVEL=    .89 METERS BELOW SURFACE,  DILUTION=  20.90
1
  UNIVERSAL DATA FILE: DIFFUSER4.DAT

  #27 Simulation of Wright, et al diffuser data, Run 6-11-A
  0 1 0 0 0 0 0
 0.0002530         10  .00953   0.         1.
      0.     90.       0.051
         2    1.0000        0.
     00.00 1.007828    0.0
    1.00   1.01720     0.
1
                                          PROGRAM UDKHDEN
                         SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
                         AMBIENT CURRENTS AND VERTICAL GRADIENTS.   AUG 1985

    UNIVERSAL DATA FILE: DIFFUSER4.DAT
    CASE I.D.  #27 Simulation of Wright, et al diffuser data, Run 6-11-A
    DISCHARGE=  .0003 CU-M/S  DENSITY=1.00000 G/CM3  ** DIAMETER=  .0095-M
    ** NUMBER OF PORTS=  10  ** SPACING=    .05-M  ** DEPTH=   1.00-M
0         AMBIENT STRATIFICATION PROFILE
     DEPTH (M)    DENSITY (G/CM3)   VELOCITY (M/S)
          .00        1.00783            .000
         1.00        1.01720            .000
0   FROUDE NO=  8.85,  PORT SPACING/PORT DIA=      5.35,
+                                                       STARTING LENGTH=     .057

    ALL LENGTHS ARE IN METERS-TIME IN SEC.  FIRST LINE ARE INITIAL CONDITIONS.
      X       Y       Z      TH1      TH2      WIDTH     DUCL     DRHO      DCCL      TIME   DILUTIOI

     .00     .00     .00   90.00      .00      .01    1.000    1.000     1.000       .00     1.00
    0.00     .06    0.00   90.00     6.06      .03    1.000     .992      .994       .16     1.94

    PLUMES MERGING

    0.00     .13     .02   90.00    25.19      .07     .394     .340      .356       .57     5.36
    0.00     .19     .07   90.00    43.37      .09     .329     .192      .240      1.19     7.35
    0.00     .24     .12   90.00    52.91      .10     .284     .093      .171      1.93     9.01
    0.00     .29     .19   90.00    56.98      .13     .250     .028      .136      2.77    10.45

    PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

    0.00     .33     .25   90.00    57.10      .16     .224    -.022      .122      3.67    11.71
    0.00     .37     .31   90.00    51.52      .22     .179    -.067      .112      4.73    12.77
    0.00     .43     .36   90.00    24.09      .36     .115    -.101      .105      6.21    13.55

    PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT

    TRAPPING LEVEL=    .78 METERS BELOW SURFACE,  DILUTION=  11.15
1
  UNIVERSAL DATA FILE: DIFFUSER4.DAT
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```
  0 1 0 0 0 0 0
 0.0007050         10  .00953   0.         1.
      0.      90.       0.102
         2    1.0000         0.
      00.00 1.010537    0.0
   1.00   1.01690     0.
1
                                  PROGRAM UDKHDEN
                         SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
                         AMBIENT CURRENTS AND VERTICAL GRADIENTS.   AUG 1985

   UNIVERSAL DATA FILE: DIFFUSER4.DAT
   CASE I.D.  #28 Simulation of Wright, et al diffuser data, Run 6-11-B
   DISCHARGE=  .0007 CU-M/S  DENSITY=1.00000 G/CM3  ** DIAMETER=  .0095-M
   ** NUMBER OF PORTS=  10  ** SPACING=    .10-M  ** DEPTH=   1.00-M
0          AMBIENT STRATIFICATION PROFILE
    DEPTH (M)    DENSITY (G/CM3)   VELOCITY (M/S)
        .00        1.01054            .000
       1.00        1.01690            .000
0  FROUDE NO= 24.88,  PORT SPACING/PORT DIA=     10.70,
+                                                    STARTING LENGTH=     .056

   ALL LENGTHS ARE IN METERS-TIME IN SEC.  FIRST LINE ARE INITIAL CONDITIONS.
     X       Y       Z      TH1     TH2     WIDTH     DUCL     DRHO     DCCL       TIME   DILUTION

     .00     .00     .00   90.00     .00      .01    1.000    1.000    1.000        .00     1.00
    0.00     .06    0.00   90.00     .76      .03    1.000    1.000    1.000        .06     1.93
    0.00     .13    0.00   90.00    3.76      .08     .315     .313     .314        .22     6.12

   PLUMES MERGING

    0.00     .21     .01   90.00    9.51      .13     .203     .194     .201        .53     9.58
    0.00     .28     .03   90.00   16.36      .16     .164     .141     .157        .96    11.68
    0.00     .35     .05   90.00   22.88      .18     .136     .098     .126       1.47    13.34
    0.00     .42     .09   90.00   28.17      .21     .119     .063     .105       2.08    14.70
    0.00     .49     .13   90.00   31.82      .24     .105     .034     .090       2.76    15.90
    0.00     .55     .17   90.00   33.67      .27     .101     .011     .084       3.51    16.98

   PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

    0.00     .62     .21   90.00   33.57      .30     .095    -.012     .079       4.29    18.00
    0.00     .68     .25   90.00   31.12      .34     .088    -.033     .075       5.14    18.94
    0.00     .75     .29   90.00   25.50      .39     .080    -.051     .072       6.06    19.81
    0.00     .82     .31   90.00   15.53      .45     .072    -.063     .069       7.08    20.59
    0.00     .89     .33   90.00    1.10      .50     .067    -.067     .067       8.19    21.29

   PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT

   TRAPPING LEVEL=    .81 METERS BELOW SURFACE,  DILUTION=  17.46
1
 UNIVERSAL DATA FILE: DIFFUSER4.DAT

 #29 Simulation of Wright, et al diffuser data, Run 6-13-A
 0 1 0 0 0 0 0
0.0008560         10  .00953   0.         1.
      0       90          0.203
```

```
     00.00 1.013590    0.0
    1.00   1.01840     0.
1
                                    PROGRAM UDKHDEN
                         SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
                         AMBIENT CURRENTS AND VERTICAL GRADIENTS.   AUG 1985

    UNIVERSAL DATA FILE: DIFFUSER4.DAT
    CASE I.D.  #29 Simulation of Wright, et al diffuser data, Run 6-13-A
    DISCHARGE=  .0009 CU-M/S  DENSITY=1.00000 G/CM3  ** DIAMETER=  .0095-M
    ** NUMBER OF PORTS=  10  ** SPACING=    .20-M  ** DEPTH=   1.00-M
0           AMBIENT STRATIFICATION PROFILE
     DEPTH (M)    DENSITY (G/CM3)   VELOCITY (M/S)
         .00        1.01359           .000
        1.00        1.01840           .000
0   FROUDE NO= 28.95,  PORT SPACING/PORT DIA=     21.30,
+                                                        STARTING LENGTH=     .056

    ALL LENGTHS ARE IN METERS-TIME IN SEC.  FIRST LINE ARE INITIAL CONDITIONS.
      X        Y        Z       TH1      TH2      WIDTH     DUCL      DRHO      DCCL       TIME   DILUTION

      .00      .00      .00    90.00      .00      .01    1.000     1.000     1.000       .00     1.00
     0.00      .06     0.00    90.00      .55      .03    1.000     1.000     1.000       .05     1.93
     0.00      .13     0.00    90.00     2.80      .08     .310      .309      .310       .18     6.21
     0.00      .21      .01    90.00     7.29      .14     .186      .182      .185       .45    10.41
     0.00      .28      .02    90.00    13.59      .19     .136      .124      .132       .85    14.55

    PLUMES MERGING

     0.00      .36      .04    90.00    20.59      .24     .115      .090      .107      1.37    17.94
     0.00      .43      .08    90.00    26.81      .26     .105      .064      .093      1.95    20.53
     0.00      .49      .11    90.00    31.42      .29     .097      .039      .083      2.58    22.82
     0.00      .56      .15    90.00    34.12      .31     .090      .016      .074      3.26    24.90

    PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

     0.00      .62      .20    90.00    34.67      .34     .080     -.005      .066      4.01    26.76
     0.00      .68      .24    90.00    32.64      .38     .069     -.022      .058      4.87    28.38
     0.00      .75      .28    90.00    27.11      .42     .058     -.035      .052      5.88    29.71
     0.00      .82      .31    90.00    16.59      .51     .048     -.042      .046      7.12    30.81
     0.00      .89      .32    90.00      .74      .56     .045     -.045      .045      8.49    31.77

    PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT

    TRAPPING LEVEL=    .81 METERS BELOW SURFACE,  DILUTION=  26.30
```

```
1
  UNIVERSAL DATA FILE: DIFFUSER5.DAT

  #30 Simulation of Wright, et al diffuser data, Run 6-16-A
  0 1 0 0 0 0 0
 0.0005890         10  .00953   0.         1.
       0.     90.       0.203
         2    1.0000        0.
     00.00 1.018010    0.0
   1.00   1.02550     0.
1
                                                PROGRAM UDKHDEN
                         SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
                         AMBIENT CURRENTS AND VERTICAL GRADIENTS.   AUG 1985

   UNIVERSAL DATA FILE: DIFFUSER5.DAT
   CASE I.D.  #30 Simulation of Wright, et al diffuser data, Run 6-16-A
   DISCHARGE=  .0006 CU-M/S  DENSITY=1.00000 G/CM3  ** DIAMETER=  .0095-M
   ** NUMBER OF PORTS=  10  ** SPACING=    .20-M  ** DEPTH=   1.00-M
0          AMBIENT STRATIFICATION PROFILE
    DEPTH (M)    DENSITY (G/CM3)   VELOCITY (M/S)
         .00        1.01801            .000
        1.00        1.02550            .000
0   FROUDE NO= 16.92,  PORT SPACING/PORT DIA=     21.30,
+                                                          STARTING LENGTH=     .056

   ALL LENGTHS ARE IN METERS-TIME IN SEC.  FIRST LINE ARE INITIAL CONDITIONS.
      X       Y       Z      TH1     TH2     WIDTH    DUCL     DRHO     DCCL      TIME   DILUTION

     .00     .00     .00    90.00     .00      .01    1.000    1.000    1.000      .00     1.00
    0.00     .06    0.00    90.00    1.62      .03    1.000     .999     .999      .07     1.93
    0.00     .13     .01    90.00    8.11      .08     .313     .307     .310      .26     6.22
    0.00     .21     .02    90.00   20.00      .14     .195     .174     .184      .64    10.48
    0.00     .27     .06    90.00   32.86      .18     .154     .106     .130     1.18    14.83

   PLUMES MERGING

    0.00     .33     .11    90.00   42.38      .22     .137     .059     .101     1.82    19.01
    0.00     .39     .16    90.00   47.36      .25     .127     .022     .086     2.52    22.26

   PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

    0.00     .44     .22    90.00   48.02      .28     .113    -.011     .076     3.29    25.06
    0.00     .49     .27    90.00   42.85      .33     .090    -.037     .066     4.19    27.36
    0.00     .55     .31    90.00   23.36      .42     .058    -.049     .053     5.47    28.99

   PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT

   TRAPPING LEVEL=    .80 METERS BELOW SURFACE,  DILUTION=  24.14
1
  UNIVERSAL DATA FILE: DIFFUSER5.DAT

  #31 Simulation of Wright, et al diffuser data,Run 6-16-B
  0 1 0 0 0 0 0
 0.0011300         10  .00953   0.         1.
       0.     90.       0.203
```

```
     00.00 1.01953    0.0
    1.00   1.02500    0.0
1
                                               PROGRAM UDKHDEN
                              SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
                              AMBIENT CURRENTS AND VERTICAL GRADIENTS.   AUG 1985

    UNIVERSAL DATA FILE: DIFFUSER5.DAT
    CASE I.D.  #31 Simulation of Wright, et al diffuser data,Run 6-16-B
    DISCHARGE=  .0011 CU-M/S  DENSITY=1.00000 G/CM3  ** DIAMETER=  .0095-M
    ** NUMBER OF PORTS=  10  ** SPACING=    .20-M  ** DEPTH=   1.00-M
0          AMBIENT STRATIFICATION PROFILE
     DEPTH (M)    DENSITY (G/CM3)   VELOCITY (M/S)
          .00        1.01953            .000
         1.00        1.02500            .000
0   FROUDE NO= 32.78,  PORT SPACING/PORT DIA=     21.30,
+                                                              STARTING LENGTH=     .056

    ALL LENGTHS ARE IN METERS-TIME IN SEC.  FIRST LINE ARE INITIAL CONDITIONS.
      X        Y        Z       TH1      TH2      WIDTH     DUCL      DRHO      DCCL       TIME   DILUTION

      .00      .00      .00    90.00      .00       .01    1.000     1.000     1.000       .00      1.00
     0.00      .06     0.00    90.00      .43       .03    1.000     1.000     1.000       .04      1.93
     0.00      .13     0.00    90.00     2.18       .08     .310      .309      .310       .14      6.21
     0.00      .21      .01    90.00     5.71       .14     .186      .183      .185       .34     10.41
     0.00      .28      .02    90.00    10.78       .20     .135      .127      .133       .65     14.53

    PLUMES MERGING

     0.00      .36      .04    90.00    16.73       .24     .113      .096      .108      1.05     17.86
     0.00      .43      .06    90.00    22.50       .27     .102      .074      .094      1.50     20.38
     0.00      .50      .09    90.00    27.38       .29     .094      .053      .084      1.99     22.60
     0.00      .56      .13    90.00    31.00       .31     .087      .033      .075      2.52     24.61
     0.00      .63      .17    90.00    33.18       .34     .080      .014      .067      3.10     26.44

    PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

     0.00      .69      .21    90.00    33.77       .37     .072     -.002      .060      3.73     28.08
     0.00      .76      .26    90.00    32.54       .40     .062     -.016      .053      4.45     29.52
     0.00      .82      .29    90.00    28.99       .46     .053     -.026      .046      5.27     30.77
     0.00      .89      .33    90.00    22.36       .52     .048     -.035      .045      6.22     31.83
     0.00      .96      .35    90.00    11.84       .59     .044     -.041      .043      7.26     32.79
     0.00     1.04      .36    90.00    -1.90       .63     .042     -.042      .042      8.37     33.67

    PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT

    TRAPPING LEVEL=    .79 METERS BELOW SURFACE,  DILUTION=  27.85
1
  UNIVERSAL DATA FILE: DIFFUSER5.DAT

  #32 Simulation of Wright, et al diffuser data, Run 6-18-B
  0 1 0 0 0 0 0
 0.0000656         10  .00318   0.         1.
      0.       90.       0.051
         2    1.0000        0.
     00.00 1.00511     0.0
```

```
1
                                               PROGRAM UDKHDEN
                               SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
                               AMBIENT CURRENTS AND VERTICAL GRADIENTS.   AUG 1985

    UNIVERSAL DATA FILE: DIFFUSER5.DAT
    CASE I.D.  #32 Simulation of Wright, et al diffuser data, Run 6-18-B
    DISCHARGE=  .0001 CU-M/S  DENSITY=1.00000 G/CM3  ** DIAMETER=  .0032-M
    ** NUMBER OF PORTS=  10  ** SPACING=    .05-M  ** DEPTH=   1.00-M
0          AMBIENT STRATIFICATION PROFILE
     DEPTH (M)    DENSITY (G/CM3)   VELOCITY (M/S)
          .00        1.00511            .000
         1.00        1.01250            .000
0   FROUDE NO= 41.85,  PORT SPACING/PORT DIA=     16.04,
+                                                               STARTING LENGTH=     .019

    ALL LENGTHS ARE IN METERS-TIME IN SEC.  FIRST LINE ARE INITIAL CONDITIONS.
      X        Y        Z       TH1      TH2     WIDTH     DUCL     DRHO     DCCL       TIME   DILUTION

      .00      .00      .00    90.00      .00     0.00    1.000    1.000    1.000        .00      1.00
     0.00      .02     0.00    90.00      .27      .01    1.000    1.000    1.000        .02      1.93
     0.00      .04     0.00    90.00     1.34      .03     .312     .311     .311        .09      6.18
     0.00      .07     0.00    90.00     3.51      .05     .187     .185     .187        .22     10.32

    PLUMES MERGING

     0.00      .09     0.00    90.00     6.63      .06     .141     .137     .140        .41     13.70
     0.00      .12      .01    90.00    10.26      .07     .121     .112     .119        .65     15.97
     0.00      .14      .01    90.00    14.07      .08     .105     .090     .102        .92     17.85
     0.00      .17      .02    90.00    17.78      .09     .092     .071     .087       1.24     19.46
     0.00      .19      .03    90.00    21.16      .10     .081     .054     .076       1.59     20.86
     0.00      .22      .04    90.00    24.05      .11     .076     .041     .069       1.99     22.10
     0.00      .24      .05    90.00    26.32      .12     .068     .027     .061       2.42     23.24
     0.00      .26      .06    90.00    27.91      .13     .066     .016     .059       2.88     24.29

    PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

     0.00      .31      .08    90.00    28.79      .15     .062    -.005     .054       3.84     26.28
     0.00      .33      .10    90.00    27.92      .16     .059    -.015     .052       4.34     27.22
     0.00      .35      .11    90.00    26.01      .17     .056    -.024     .051       4.88     28.11
     0.00      .38      .12    90.00    22.87      .19     .053    -.032     .049       5.44     28.95
     0.00      .40      .13    90.00    18.30      .21     .050    -.038     .048       6.03     29.75
     0.00      .42      .13    90.00    12.19      .22     .048    -.043     .047       6.66     30.50
     0.00      .45      .14    90.00     4.70      .24     .046    -.045     .046       7.32     31.21

    PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT

    TRAPPING LEVEL=    .92 METERS BELOW SURFACE,  DILUTION=  25.84
1
  UNIVERSAL DATA FILE: DIFFUSER5.DAT

  #33 Simulation of Wright, et al diffuser data, Run 6-19-A
  0 1 0 0 0 0 0
 0.0001280         10  .00318   0.         1.
      0.    90.       0.102
        2    1.0000         0
```

```
    1.00   1.01230     0.0
1
                                          PROGRAM UDKHDEN
                            SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
                            AMBIENT CURRENTS AND VERTICAL GRADIENTS.   AUG 1985

    UNIVERSAL DATA FILE: DIFFUSER5.DAT
    CASE I.D.  #33 Simulation of Wright, et al diffuser data, Run 6-19-A
    DISCHARGE=  .0001 CU-M/S  DENSITY=1.00000 G/CM3  ** DIAMETER=  .0032-M
    ** NUMBER OF PORTS=  10  ** SPACING=    .10-M  ** DEPTH=   1.00-M
0          AMBIENT STRATIFICATION PROFILE
     DEPTH (M)    DENSITY (G/CM3)   VELOCITY (M/S)
         .00        1.00662            .000
        1.00        1.01230            .000
0   FROUDE NO= 82.32,  PORT SPACING/PORT DIA=     32.08,
+                                                          STARTING LENGTH=     .019

    ALL LENGTHS ARE IN METERS-TIME IN SEC.  FIRST LINE ARE INITIAL CONDITIONS.
      X        Y        Z      TH1      TH2     WIDTH     DUCL     DRHO     DCCL       TIME   DILUTION

      .00      .00      .00    90.00      .00     0.00    1.000    1.000    1.000        .00      1.00
     0.00      .02     0.00    90.00      .07      .01    1.000    1.000    1.000        .01      1.93
     0.00      .04     0.00    90.00      .35      .03     .308     .308     .308        .04      6.24
     0.00      .07     0.00    90.00      .92      .05     .183     .183     .183        .11     10.50
     0.00      .09     0.00    90.00     1.78      .07     .131     .131     .131        .22     14.69
     0.00      .12     0.00    90.00     2.91      .08     .102     .101     .102        .35     18.81

    PLUMES MERGING

     0.00      .15     0.00    90.00     4.29      .10     .084     .082     .084        .52     22.88
     0.00      .17      .01    90.00     5.87      .12     .074     .070     .074        .72     26.02
     0.00      .20      .01    90.00     7.56      .13     .068     .061     .067        .95     28.57
     0.00      .22      .01    90.00     9.28      .14     .063     .053     .062       1.19     30.82
     0.00      .25      .02    90.00    10.98      .15     .058     .045     .057       1.45     32.86
     0.00      .27      .02    90.00    12.60      .16     .054     .038     .053       1.73     34.73
     0.00      .32      .03    90.00    15.35      .18     .047     .023     .045       2.35     38.04
     0.00      .37      .05    90.00    17.12      .20     .041     .009     .039       3.07     40.87

    PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

     0.00      .42      .06    90.00    17.58      .21     .037    -.002     .035       3.89     43.32
     0.00      .44      .07    90.00    17.24      .24     .034    -.007     .032       4.33     44.45
     0.00      .47      .08    90.00    16.47      .25     .033    -.011     .031       4.81     45.49
     0.00      .49      .09    90.00    15.25      .26     .032    -.016     .031       5.30     46.49
     0.00      .52      .09    90.00    13.57      .27     .031    -.020     .030       5.80     47.46
     0.00      .54      .10    90.00    11.42      .28     .030    -.023     .029       6.32     48.40
     0.00      .57      .10    90.00     8.82      .30     .029    -.025     .029       6.85     49.32
     0.00      .59      .11    90.00     5.82      .31     .029    -.027     .028       7.40     50.21
     0.00      .62      .11    90.00     2.52      .32     .028    -.028     .028       7.96     51.07
     0.00      .64      .11    90.00     -.96      .33     .027    -.027     .027       8.53     51.92

    PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT

    TRAPPING LEVEL=    .94 METERS BELOW SURFACE,  DILUTION=  42.89
1
  UNIVERSAL DATA FILE: DIFFUSER5.DAT
```

```
 #34 Simulation of Wright, et al diffuser data,Run 6-19-B
 0 1 0 0 0 0 0
0.0001850        10  .00318   0.         1.
     0.     90.       0.152
        2   1.0000        0.
     00.00 1.00851    0.0
   1.00   1.01250     0.0
1
                                  PROGRAM UDKHDEN
                       SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
                       AMBIENT CURRENTS AND VERTICAL GRADIENTS.   AUG 1985

   UNIVERSAL DATA FILE: DIFFUSER5.DAT
   CASE I.D.  #34 Simulation of Wright, et al diffuser data,Run 6-19-B
   DISCHARGE=  .0002 CU-M/S  DENSITY=1.00000 G/CM3  ** DIAMETER=  .0032-M
   ** NUMBER OF PORTS=  10  ** SPACING=    .15-M  ** DEPTH=   1.00-M
0         AMBIENT STRATIFICATION PROFILE
    DEPTH (M)    DENSITY (G/CM3)   VELOCITY (M/S)
         .00        1.00851            .000
        1.00        1.01250            .000
0  FROUDE NO=118.02,  PORT SPACING/PORT DIA=     47.80,
+                                                     STARTING LENGTH=     .018

   ALL LENGTHS ARE IN METERS-TIME IN SEC.  FIRST LINE ARE INITIAL CONDITIONS.
     X        Y        Z       TH1      TH2      WIDTH     DUCL      DRHO      DCCL       TIME   DILUTION

    .00      .00      .00    90.00      .00     0.00    1.000     1.000     1.000        .00      1.00
   0.00      .02     0.00    90.00      .03      .01    1.000     1.000     1.000        .01      1.93
   0.00      .04     0.00    90.00      .17      .03     .307      .307      .307        .03      6.26
   0.00      .07     0.00    90.00      .45      .05     .182      .182      .182        .08     10.56
   0.00      .09     0.00    90.00      .87      .07     .130      .130      .130        .15     14.81
   0.00      .12     0.00    90.00     1.43      .09     .101      .101      .101        .25     19.02
   0.00      .15     0.00    90.00     2.12      .10     .083      .082      .083        .37     23.18
   0.00      .17     0.00    90.00     2.95      .12     .071      .069      .071        .51     27.30
   0.00      .20     0.00    90.00     3.89      .14     .062      .059      .061        .67     31.38

   PLUMES MERGING

   0.00      .22      .01    90.00     4.94      .16     .055      .052      .055        .86     35.26
   0.00      .25      .01    90.00     6.06      .17     .051      .046      .050       1.07     38.30
   0.00      .27      .01    90.00     7.21      .18     .047      .041      .047       1.29     40.95
   0.00      .32      .02    90.00     9.52      .21     .042      .033      .042       1.78     45.59
   0.00      .37      .03    90.00    11.63      .22     .038      .024      .038       2.32     49.64
   0.00      .42      .04    90.00    13.36      .24     .035      .015      .034       2.92     53.25
   0.00      .47      .05    90.00    14.50      .26     .032      .007      .031       3.57     56.48

   PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

   0.00      .52      .06    90.00    14.91      .28     .029     0.000      .028       4.30     59.36
   0.00      .55      .07    90.00    14.80      .29     .027     -.003      .026       4.69     60.69
   0.00      .57      .08    90.00    14.45      .30     .026     -.006      .025       5.11     61.94
   0.00      .59      .08    90.00    13.86      .31     .025     -.009      .024       5.54     63.13
   0.00      .62      .09    90.00    13.01      .32     .024     -.012      .024       5.98     64.29
   0.00      .64      .10    90.00    11.90      .35     .022     -.013      .022       6.45     65.39
   0.00      .67      .10    90.00    10.54      .36     .022     -.015      .021       6.94     66.41
   0.00      .69      .10    90.00     8.93      .38     .021     -.017      .021       7.45     67.42
```

```
      0.00      .74      .11    90.00     5.05        .40      .021     -.019       .021        8.49     69.36
      0.00      .77      .11    90.00     2.84        .41      .020     -.020       .020        9.02     70.30
      0.00      .80      .11    90.00      .53        .42      .020     -.020       .020        9.56     71.23

     PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT

     TRAPPING LEVEL=    .94 METERS BELOW SURFACE,  DILUTION=  59.34
1
   UNIVERSAL DATA FILE: DIFFUSER5.DAT

   #35 Simulation of Wright, et al diffuser data, Run 6-23-A
   0 1 0 0 0 0 0
  0.0002430         10  .00318   0.         1.
        0.     90.       0.203
            2    1.0000        0.
         00.00 1.005677    0.0
       1.00   1.01150     0.
1
                                             PROGRAM UDKHDEN
                               SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
                               AMBIENT CURRENTS AND VERTICAL GRADIENTS.   AUG 1985

     UNIVERSAL DATA FILE: DIFFUSER5.DAT
     CASE I.D.  #35 Simulation of Wright, et al diffuser data, Run 6-23-A
     DISCHARGE=  .0002 CU-M/S  DENSITY=1.00000 G/CM3  ** DIAMETER=  .0032-M
     ** NUMBER OF PORTS=  10  ** SPACING=     .20-M  ** DEPTH=   1.00-M
0             AMBIENT STRATIFICATION PROFILE
      DEPTH (M)    DENSITY (G/CM3)   VELOCITY (M/S)
           .00        1.00568            .000
          1.00        1.01150            .000
0    FROUDE NO=161.62,  PORT SPACING/PORT DIA=     63.84,
+                                                              STARTING LENGTH=     .018

     ALL LENGTHS ARE IN METERS-TIME IN SEC.  FIRST LINE ARE INITIAL CONDITIONS.
        X        Y        Z       TH1      TH2      WIDTH     DUCL      DRHO      DCCL       TIME   DILUTION

        .00      .00      .00    90.00      .00     0.00     1.000     1.000     1.000       .00      1.00
       0.00      .02     0.00    90.00      .02      .01     1.000     1.000     1.000       .01      1.93
       0.00      .04     0.00    90.00      .09      .03      .307      .307      .307       .02      6.27
       0.00      .07     0.00    90.00      .24      .05      .182      .182      .182       .06     10.59
       0.00      .09     0.00    90.00      .46      .07      .130      .129      .129       .11     14.87
       0.00      .12     0.00    90.00      .77      .09      .101      .100      .101       .19     19.12
       0.00      .15     0.00    90.00     1.14      .11      .083      .082      .083       .28     23.34
       0.00      .17     0.00    90.00     1.58      .12      .070      .069      .070       .39     27.52
       0.00      .20     0.00    90.00     2.09      .14      .061      .059      .061       .52     31.67
       0.00      .22     0.00    90.00     2.67      .16      .054      .051      .054       .66     35.79
       0.00      .25     0.00    90.00     3.30      .18      .048      .045      .048       .83     39.88
       0.00      .27      .01    90.00     3.97      .20      .044      .039      .044      1.01     43.94

     PLUMES MERGING

       0.00      .32      .01    90.00     5.37      .23      .038      .030      .038      1.41     50.65
       0.00      .37      .02    90.00     6.71      .25      .035      .022      .034      1.87     55.87
       0.00      .42      .02    90.00     7.82      .27      .032      .014      .032      2.37     60.45
       0.00      .47      .03    90.00     8.56      .29      .030      .007      .029      2.92     64.57
```

```
     0.00      .53      .04   90.00    8.78      .31      .027    -.001      .027      3.50    68.32
     0.00      .55      .04   90.00    8.66      .32      .026    -.004      .026      3.81    70.07
     0.00      .58      .04   90.00    8.38      .33      .025    -.008      .025      4.13    71.74
     0.00      .60      .05   90.00    7.92      .34      .024    -.010      .024      4.47    73.34
     0.00      .63      .05   90.00    7.29      .35      .023    -.013      .023      4.82    74.86
     0.00      .65      .05   90.00    6.48      .36      .022    -.015      .022      5.19    76.31
     0.00      .68      .06   90.00    5.51      .37      .021    -.017      .021      5.57    77.71
     0.00      .70      .06   90.00    4.38      .39      .020    -.018      .020      5.97    79.03
     0.00      .73      .06   90.00    3.12      .40      .020    -.018      .020      6.38    80.30
     0.00      .75      .06   90.00    1.76      .41      .019    -.019      .019      6.81    81.51
     0.00      .78      .06   90.00     .33      .41      .019    -.019      .019      7.26    82.69

    PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT

    TRAPPING LEVEL=    .96 METERS BELOW SURFACE,  DILUTION=  67.89
1
  UNIVERSAL DATA FILE: DIFFUSER5.DAT

  #36 Simulation of Wright, et al diffuser data, Run 6-24-B
  0 1 0 0 0 0 0
 0.0000473        10  .00318   0.        1.
      0.      90.       0.051
         2    1.0000        0.
      00.00 1.00534     0.0
    1.00   1.00940     0.
1
                                  PROGRAM UDKHDEN
                        SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
                        AMBIENT CURRENTS AND VERTICAL GRADIENTS.   AUG 1985

    UNIVERSAL DATA FILE: DIFFUSER5.DAT
    CASE I.D.  #36 Simulation of Wright, et al diffuser data, Run 6-24-B
    DISCHARGE= 0.0000 CU-M/S  DENSITY=1.00000 G/CM3  ** DIAMETER=  .0032-M
    ** NUMBER OF PORTS=  10  ** SPACING=    .05-M  ** DEPTH=   1.00-M
0          AMBIENT STRATIFICATION PROFILE
     DEPTH (M)    DENSITY (G/CM3)   VELOCITY (M/S)
         .00        1.00534           .000
        1.00        1.00940           .000
0   FROUDE NO= 34.80,  PORT SPACING/PORT DIA=     16.04,
+                                                         STARTING LENGTH=     .019

    ALL LENGTHS ARE IN METERS-TIME IN SEC.  FIRST LINE ARE INITIAL CONDITIONS.
      X         Y         Z       TH1      TH2      WIDTH     DUCL      DRHO      DCCL       TIME   DILUTION

      .00      .00      .00   90.00     .00     0.00     1.000     1.000     1.000       .00     1.00
     0.00      .02     0.00   90.00     .38      .01     1.000     1.000     1.000       .03     1.93
     0.00      .04     0.00   90.00    1.94      .03      .312      .311      .311       .12     6.18
     0.00      .07     0.00   90.00    5.06      .05      .187      .185      .187       .30    10.32

    PLUMES MERGING

     0.00      .09      .01   90.00    9.52      .06      .142      .137      .140       .57    13.73
     0.00      .12      .01   90.00   14.60      .07      .122      .112      .118       .89    16.02
     0.00      .14      .02   90.00   19.74      .08      .108      .090      .102      1.27    17.94
     0.00      .17      .03   90.00   24.54      .09      .097      .071      .088      1.68    19.62
```

```
 0.00     .21     .05   90.00   32.16      .10     .081     .040     .069     2.66    22.45
 0.00     .23     .07   90.00   34.78      .11     .079     .029     .065     3.19    23.71
 0.00     .25     .08   90.00   36.60      .12     .071     .017     .057     3.78    24.87

PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

 0.00     .29     .11   90.00   37.77      .14     .067    -.003     .053     5.01    27.02
 0.00     .31     .13   90.00   36.99      .15     .064    -.012     .051     5.67    28.03
 0.00     .34     .14   90.00   35.09      .17     .060    -.021     .049     6.36    28.99
 0.00     .36     .16   90.00   31.74      .19     .056    -.029     .048     7.09    29.88
 0.00     .38     .17   90.00   26.49      .21     .052    -.036     .046     7.89    30.71
 0.00     .40     .18   90.00   18.76      .23     .048    -.041     .045     8.74    31.47
 0.00     .43     .18   90.00    8.33      .25     .045    -.044     .044     9.67    32.18
 0.00     .45     .19   90.00   -3.84      .26     .043    -.043     .043    10.64    32.85

PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT

TRAPPING LEVEL=    .89 METERS BELOW SURFACE,  DILUTION=  26.69
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APPENDIX 2

RELEVANT PUBLICATIONS

CONTROL OF BUOYANT JET MIXING BY FAR FIELD SPREADING

By Steven J. Wright*, A.M. ASCE and Johannes Buhler**, M. ASCE

Summary

The estimate of near-field dilution for a submerged buoyant jet discharge is considered. The mixing processes include the submerged buoyant jet entrainment and the mixing after impingement upon the free surface as the flow spreads as a surface layer. This latter mixing process is confined to a near source region and is limited by the far field spreading. The case of unsteady density current propagation is considered as the specific far field control. Theoretical models for density current propagation are found to be inconsistent and a new formulation is proposed. The results of the model prediction are compared against various experimental data.

Introduction

Since many pollution control regulations for discharges from submerged outfall diffusers are written in terms of permissible near field dilutions, an analysis must include not only an estimate of the submerged jet mixing, but also any influence due to the impingement of the discharge upon the surface and the subsequent gravitational spread. The worst case for dilution is generally with zero ambient current and the problem of a two-dimensional diffuser in stagnant surroundings as depicted in Fig. 1 is considered in this analysis. The surface layer thicknesses are found to be at least 30 percent of the total depth according to various studies (e.g. Buhler (1973), Roberts (1977), etc). Therefore, the description of the layer influence may have a large effect on the estimated near field dilution.

A previous method by Koh (1983) assumes that the far field layer thickness is controlled by density current spreading. Although this unsteady flow problem may not be directly applicable to prototype problems, it is a typical configuration in laboratory studies. Koh predicts the density current thickness as a function of the jet volume and buoyancy fluxes and assumes that this layer serves to block the jet mixing process, i.e. no further dilution occurs above the level of the bottom of the spreading layer. By coupling the two submodels together, the near field dilution is taken as that predicted by the submerged jet model at the bottom of the spreading layer. This method underpredicts the dilutions observed in a variety of experiments, as discussed by Wright (1985a).

A related method by Jirka and Harleman (1979) assumes that the layer thickness where the jet impinges upon the surface is determined by local energy considerations and is not directly coupled to the far field. The surface layer thickness then increases by an internal hydraulic jump in

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an analysis that assumes no mixing. In the analysis, there is no far field control unless the jump is unstable and locally mixes over the entire depth. Jirka and Harleman's model predicts larger dilutions for unflooded internal jumps than Koh's method because of the smaller blocking layer thickness in the vicinity of the source.

The present analysis is an extension of the previous discussion by Wright (1985a). In that work, the surface flow was assumed to undergo further dilution through a density jump as described by Wilkinson and Wood (1971). In order to apply their analysis, a downstream control is required. Wright used Koh's far field spreading model directly to demonstrate the differences in the two near field analyses. This study attempts to include a more correct and complete handling of the far field spreading from the analyses of Benjamin (1969) and others. It will be shown that certain inconsistencies result in the direct application of this theory. An explanation for the resolution of the contradictions is put forth and the resulting model is developed. Finally, the model formulation is compared against a variety of experimental data to show that reasonable predictions for the near field dilution are achieved.

Submodels

The complete problem is handled by application of successive submodels. The approach is similar to that of Koh or Jirka and Harleman except for the specifics of the various submodels. The methodology may be regarded as approximate due to the inability to precisely describe the interactions of the various flow phenomena, but is sufficiently accurate for the intended purpose of predicting near-field dilutions.

Submerged Jet Model

The work by Buhler (1973) shows that submerged manifold diffusers can often be analyzed as a line plume, for which an analytical solution is available. For other cases, various numerical integral models can be invoked that differ little in their conceptual description of the interactions between adjacent jets. The model described by Wright, et al (1982) is used herein. The model predicts the variation of fluxes of volume $q = \int u \, dA$, momentum $m = \int u^2 \, dA$, and buoyancy $\beta = \int u g' \, dA$ along the jet trajectory, where u is velocity and g' is the reduced gravitational acceleration associated with local density differences between the jet and ambient fluids. For this study, the rows of jets on

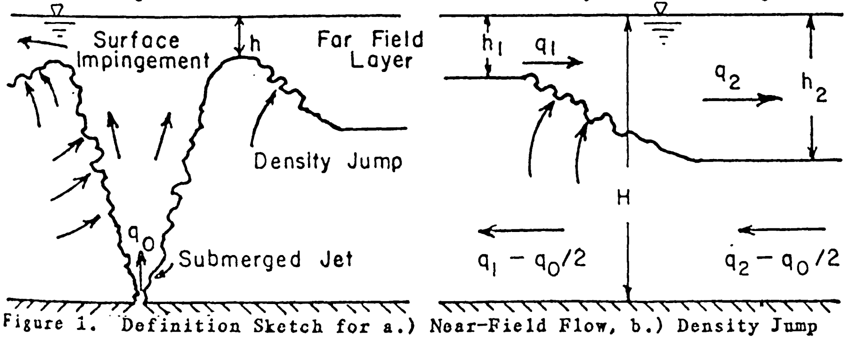

Figure 1. Definition Sketch for a.) Near-Field Flow, b.) Density Jump

either side of the diffuser are assumed to form a single vertical flow after the individual jets on one side are computed to be merged (transition from round to two-dimensional jets). In the original model, the volume flux was made discontinuous at merging to force the model to predict continuous minimum dilutions since all characteristic variables cannot be kept continuous with the approximate description of the merging process. In this study, it is preferred to accept discontinuities in the minimum dilution because the the volume flux enters directly into subsequent computations. For this reason, it should be expected that predictions of minimum jet dilution will be somewhat inaccurate when the jet merging is close to the surface. The subsequent development thus concentrates on the prediction of average dilution $S = q/q_0$, where q_0 is the source discharge. In order to compare the predictions against experimental data in which only the concentration of a tracer is known, the approach by Buhler (1983) is followed in which the average concentration c is computed from the first two moments of the concentration distribution, $ch = \int c\, dA$ and $ch^2/2 = \int cy\, dA$ where y is distance from the centerline for a free jet or boundary for a wall jet.

Surface Impingement

The methodology of Jirka and Harleman (1979) is adopted for the description of the jet impingement on the surface (Fig. 1). Their analysis assumes continuity of flow and energy conservation including a loss term but indicate the results are not too sensitive to estimates of loss coefficients. In the present analysis, the predicted near field dilution will be more dependent upon the selected loss coefficient and other assumptions regarding velocity and density profiles. The loss coefficient $k_L = 0.2$ and uniform velocity and density profiles in the surface flow suggested by Jirka and Harleman were used in the present formulation. This surface impingement is formulated in terms of the jet fluxes and surface layer thickness h as:

$$\left[\frac{q}{4h}\right]^3 - \frac{(1-k_L)}{2\sqrt{3}}\left[\frac{m}{q}\right]^2\left[\frac{q}{4h}\right] - \frac{\beta}{16} = 0 \qquad (1)$$

Eq. 1 is used directly with the submerged jet model to determine when the remaining distance to the free surface and h are equal. This then defines the input conditions for the density jump model.

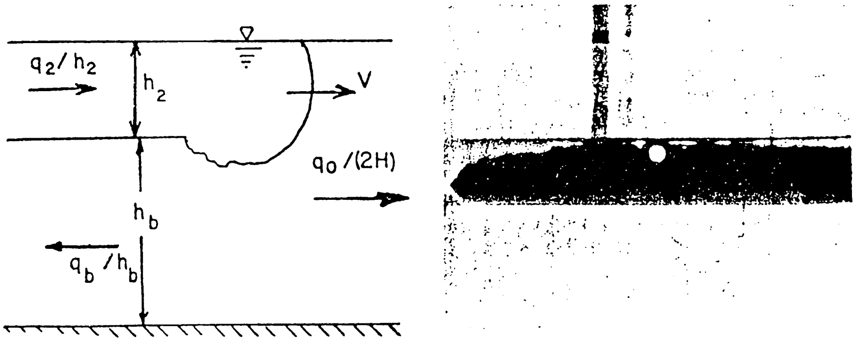

Figure 2. a.)Definition Sketch for Density Current, b.) Photo, Run 25A

Density Jump

The methodology of Wilkinson and Wood (1971) is employed in this submodel. The problem is indicated schematically in Fig. 1b and follows directly from Wright (1985a). Uniform profiles of density and velocity are assumed, although nonuniform profiles can be included by a series of integral constants, as discussed by Wright (1985b). The equations are

$$\frac{q_1^2}{h_1} + \frac{(q_1 - q_0/2)^2}{H-h_1} - \frac{q_2^2}{h_2} - \frac{(q_2 - q_0/2)^2}{H-h_2} + \frac{\beta h_1^2}{4q_1} - \frac{\beta h_2^2}{4q_2} = 0 \qquad (2)$$

Major differences from the model by Jirka and Harleman are that mixing is assumed to occur in the surface flow and that in this formulation, a downstream control is required.

Downstream Control

Wilkinson and Wood's (1971) original hypothesis was that the layer Froude numbers $F_u^2 + F_b^2 = q_u^2/g'h_u^3 + q_b^2/g'h_b^3$ (where the subscripts u and b refer to the upper and bottom layers, respectively) in the absence of other downstream control would decrease from an initially supercritical state until the internal interfacial waves are blocked from upstream propagation, i.e., the flow is internally critical. This has been verified by Wright (1985b). The downstream control to be considered herein is the unsteady density current indicated in Fig. 2. Although Koh (1983) considers the same problem, he used the solution for infinite depth and adjusted it to account for the relative velocity in the return layer. The analysis by Benjamin (1969) yields a propagation velocity that is dependent upon the fractional depth $\eta = h_2/H$ of the spreading layer. His analysis is independent of the relative velocity between layers and is applied to the present problem by assuming that an induced flow of $q_0/2H$ is generated ahead of the density current to satisfy the overall continuity of the system. Expressed in this framework, Benjamin's result is

$$c^2/(g'h_2) = [q_2/h_2 - q_0/(2H)]^2/(g'h_2) = (1-\eta)(2-\eta)/(1+\eta) \qquad (3)$$

Benjamin shows that $\eta \leq 0.5$ to satisfy the requirement of no energy gain across the jump. Kranenburg (1978) extended this to show that a necessary condition for the density current to propagate as a shock is that $\eta \leq 0.347$. This is based upon the condition that the return flow in the lower can be at most critical with respect to the head. However, this can be shown to lead to a logical contradiction. Consider a situation where the layer depth might otherwise be in excess of the stated criterion (either greater than 0.5H for Benjamin or 0.347H for Kranenburg). Then, according to the argument by Kranenburg, the layer depth is restricted to the value imposed by the appropriate limit. If so, the layer depth and propagation velocity are fixed, which in turn uniquely determines the volume flux in the layer. The following relations can be derived for the two cases:

Benjamin $\quad S(S-1/2)^2 = \beta H^3/(4q_0^3) \qquad (4)$
Kranenburg $\quad S(S-0.347)^2 = 0.134\beta H^3/q_0^3 \qquad (5)$

Although Buhler (1977) interpreted his data to imply Eq. 4 to be a valid description, it will be shown below that his results can also be described by the present formulation which is more consistent with other observations. The solution to Eq. 3 is presented in Fig. 3 in the form of $F_u^2 + F_b^2$ in a stationary frame of reference. It is presumed that when the density current is subcritical, it serves as the downstream control for the density jump. However, it can be seen that the density current flow would be supercritical for many source conditions. This implies that the density current should not act as a downstream control because the density jump would mix to an internally critical state otherwise. However, Eqs. 4 or 5 imply that the near field dilution is uniquely fixed by the density current regardless of the nature of the submerged jet mixing or the density jump. The apparent contradiction can be resolved by suggesting that the arguments by Benjamin or Kranenburg only provide a limit to the applicability of their theory. For the purposes of the present analysis, it is simply specified that critical flow in the return layer at the head occurs for layer depths in excess of 0.347H. For the present problem, this may be used to derive the sum of the layer Froude numbers:

$$F_u^2 = (1-\eta)^3/\eta + 2(1-\eta)^{3/2}F_A/\eta + F_A^2/\eta \tag{6}$$

and

$$F_u^2 + F_b^2 = 1 - 2F_u[\eta/(1-\eta)]^{1/2} + F_u^2/(1-\eta)$$

where $F_A^2 = (q_0/2H)^2/(g'H)$. The predictions of Eq. 6 are also plotted in Figure 3 with the intersection at $\eta = 0.347$. All predictions generated below utilize this description to prescribe the downstream control, namely if the sum of the layer Froude numbers gives a

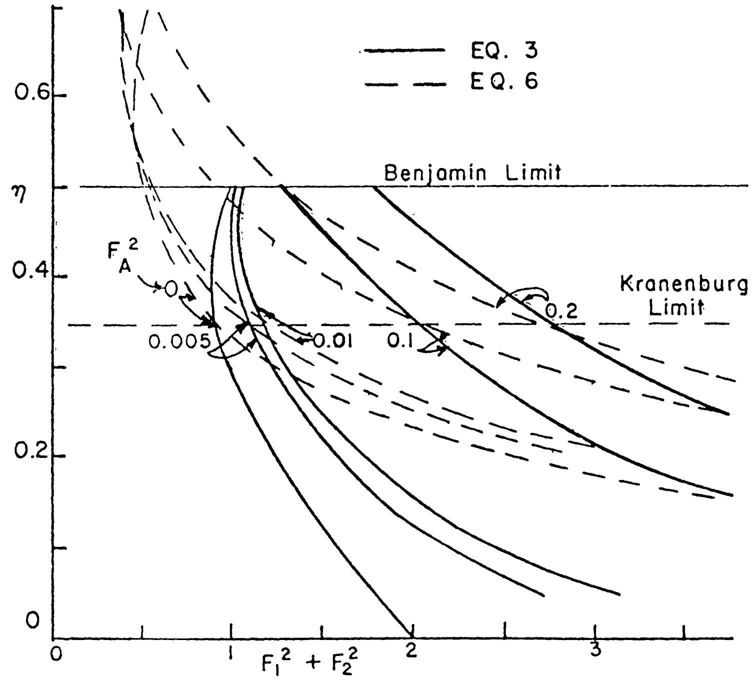

Figure. 3. Variation of Layer Froude Numbers with Fractional Depth.

subcritical state, Eq. 3 is applied for $\eta < 0.347$ and Eq. 6 for $\eta > 0.347$. If the density current Froude numbers are supercritical (small η or large F_A), the density jump is assumed to mix to an internally critical state. It should be noted that none of the experimental data presented below is in a range where the latter criterion is applied.

It should also be noted that interfacial friction has been ignored. If its effect is included in the analysis, there is an inability to maintain a steady state far-field flow. However, it appears that this is not too important for most laboratory investigations. In a prototype situation, however, it is not clear that there will be a far field density current except for starting flows that only rarely occur in practice. Therefore the role of friction, far field currents, and three-dimensional spreading effects may be dominant in those cases.

Experimental Investigations

At present, the detailed investigation needed to verify all the aspects of the above analysis has not been conducted. However, there is a fair amount of data available to validate the basic components. In addition to the results discussed below, other data investigated appear to be in general agreement with the concepts developed herein.

Wallace and Sheff (1984) conducted a few experiments for slot discharges in a channel where the spreading is into a larger width at an expansion about 2H away from the source. This type of free outflow is presumed to give an internally critical section at the expansion and therefore corresponds to the solution in the absence of other downstream control. The numerical solution with the integral jet model discussed above predicts $\eta = 0.29$ and $Sq_0/(\beta^{1/3}H) = 0.46$, whereas the measured concentration profiles near the expansion section for four experiments yield average values of $\eta = 0.27$ and $Sq_0/(\beta^{1/3}H) = 0.50$ with minimal deviation between experiments. Presumably, the deviation between the measured and predicted results is within the variation that would occur with different assumed profile shapes in the surface layer.

Wright (1986) collected data on horizontal wall jets to examine specific questions associated with far field control on jet mixing. Data on the density current propagation problem was collected in addition to other results. Kranenburg's (1978) critical flow criterion may used to derive a head Froude number F_h (for spreading in one direction) independent of direct measurements of the layer thickness:

$$F_h^2 = V[V-q_0/H]^2/\beta = (1-\eta)^3/\eta = 0.80 \text{ if } \eta = 0.347 \tag{7}$$

where V is the density current speed. The density currents were photographed and their propagation velocities determined. One extreme density current is indicated in Fig. 2b. Although more detailed information on temperature profiles is also available, the visual thicknesses were often in excess of the proposed limits for η of either 0.5 or 0.347. Representative data presented in Table 1 indicate that

Table 1. Propagation Characteristics of Density Currents.

Run #	1A	3A	5A	25A	9B
$V(V-q_0/H)^2/\beta$	0.325	0.244	0.073	0.069	0.306
η from Eq. 7	0.47	0.50	0.64	0.70	0.47
Visual η	0.55	0.57	0.63	0.77	0.47

the density currents follow the critical flow relation but not the depth limitation as the predicted depths from Eq. 7 agree with those observed.

Buhler (1973) performed experiments with discharges from a manifold diffuser and the data consist of surface concentrations at the source, nine water depths away, and vertical concentration profiles at two intermediate locations which are presumed to be within the density jump. Also measured was the propagation velocity of the density current. Analysis indicated that the density current speed was the most sensitive parameter to details of the model formulation. A comparison of predicted and observed V and S (assuming the average dilution is 1.1 times the surface dilution, this was estimated from the concentration profiles) at 9H are presented in Table 2 for nine different experiments where the individual jets were computed to have merged before the surface impingement. Although there are some systematic deviations, it appears that these are due to inaccuracies in the submerged jet model.

Table 2. Comparison of Model with Data from Buhler (1973).

Run #	$V_{meas.}/q_2/h_2$	$S_{meas.}$	$S_{pred.}/1.1$ *
29	0.88	206	190
32	0.96	133	133
35	1.18	83.4	78.6
39	0.93	334	306
42	1.10	212	208
45	1.17	131	139
48	1.05	530	550
50	1.26	328	324
52	1.48	197	220

* Factor of 1.1 is observed ratio of average to minimum dilution.

Finally, Roberts (1977) performed some experiments on a slot plume and reports surface dilutions to be given by $Sq_0/(\beta^{1/3}H) = 0.27$, which is much lower than the other data investigated. However, the source Reynolds numbers are only on the order of 100-300 and it appears that these results are significantly affected by viscous effects.

Conclusions

Although the data do not cover a broad range of source conditions, the methodology outlined is fairly well supported by the available data. One result is that the blocking correction proposed by Koh is too conservative, i.e. it underpredicts the actual dilution. Another issue is that an unsteady laboratory study may have no direct relationship to a prototype flow. It is suspected that many prototype problems may not have a downstream control other than the internally critical one and therefore that a reasonable approach to an analysis may be to use that as the downstream control rather than something else that may be highly speculative in nature. The role of internal friction warrants further investigation.

Acknowledgment

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ADDENDUM TO

ASSESSMENT OF EPA PLUME MODEL UDKHDEN PREDICTIONS IN STRATIFIED AMBIENT FLUIDS

Report Prepared for

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February 21, 1987

INTRODUCTION

This addendum to the report *Assessment of EPA Plume Model UDKHDEN Predictions in Stratified Ambient Fluids* is to address issues associated with the interpretation of the field data obtained at the site of the Port Valdez ballast water diffuser. The original report concentrated solely on the interpretation of the predictions of the EPA plume model UDKHDEN in relation to available laboratory data on buoyant jets in stratified fluids. Various conclusions regarding the interpretation of the model predictions were obtained. However, these were not directly applied to the field data obtained in October, 1985 and March, 1986. One important aspect to the field data was that in the March, 1986 survey, the plume was observed to rise to the surface much of the sampling period. This addendum addresses the direct application of the previous modelling results to the October, 1985 data and describes an interpretation of the UDKHDEN output to handle the problem of surfacing plumes. The comparison of the model interpretation against the field data indicates that the predictions are within the probable uncertainty in the field data.

BACKGROUND

The original report presented a comparison of the UDKHDEN predictions versus the available experimental data from laboratory experiments in stratified fluids. The data set that was regarded as most applicable to the field application was the data on vertical round buoyant jets in linearly stratified fluids. The dilution predicted at the maximum height of rise was found to be a superior indicator of the observations than the present model implementation which uses the dilution at the neutrally buoyancy level. The ratio of predicted average dilution versus observed minimum dilution was presented as a function of the length scale ratio $\mathbf{l_m/l_b}$ in Figure 6 of the report. This indicates that the ratio of predicted average dilution to observed minimum dilution in the spreading layer ranges from about 1.7 down to about 1.3 over the range of the length scale ratio covered by the experimental data. On the basis of the conclusions presented in the report, the field data was interpreted on the same basis and the results were transmitted in a report by Peter Mangarella dated February 6, 1987 which showed a similar trend in the comparison between model predictions and the field data collected in October, 1985. This has led to the attempt below to extend the laboratory predictions to the field data to develop a basic model correction. This is shown to work very successfully below.

The comparison of the field data collected in March, 1986 and the model predictions are complicated by the fact that the plume rose to the surface during much of the sampling period. As discussed in the previous report, the UDKHDEN model apparently uses too large of an entrainment coefficient and will under-predict the maximum height of rise due partially to that reason. This has little influence on the predicted minimum dilution since the reduction in rise height is accompanied by an increase in dilution per unit distance. This leads to the observed dilemma that the plume was predicted to be submerged in many circumstances where the actual plume was observed to be surfacing. However, both the model and the observations indicated plume surfacing during much of the sampling period. The previously mentioned report by Peter Mangarella apparently reports the predicted minimum dilution at the water surface as the predicted dilution and this over-predicts the dilution in most cases. Since the plume must spread along the surface after impingement upon it, it is not obvious that the prediction taken all the way to the free surface is a reasonable approach. Previous approaches have stopped the dilution at the bottom of the layer thickness that is predicted by a far field spreading model and has been reported to be approximately one-third of the entire depth. However, Wright, 1985 has shown such an approach to be not entirely accurate. An alternative procedure was developed that has been extended by Wright, 1986 ("Aspects of Far Field Control on Buoyant Jet Mixing," Report R24-86, Institut für Hydromechanik und Wasserwirtschaft, ETH, Zürich, Switzerland, March 1986) and Wright and Bühler, 1986. The flow is indicated schematically in Figure 2 of the original report (reproduced from Wright, 1986) and indicates a smaller near field layer followed by a surface mixing region after which the flow collapses to a non-entraining layer in the far field. The near field layer thickness for a two dimensional plume was theoretically predicted to be 16.5 percent of the entire depth. The minimum dilution directly above the diffuser is thus taken as that at 0.835 of the total depth rather than that at the total depth. Farther away, the surface jet results in an additional dilution of about 13 percent for a plume. These predictions were shown in the above references to adequately describe a variety of experimental laboratory data on both line plumes and diffuser discharges. These corrections are applied to the UDKHDEN predictions and are shown to account for much of the reported discrepancies between predicted and observed dilutions.

The two sets of field data are interpreted separately due to the fundamentally different nature of the flow behavior in the two situations.

OCTOBER, 1985 DATA

The model predicts the plume to be submerged during the entire test period and the field observations also indicate the waste field to be submerged as well. Therefore, the interpretation of the field data is taken entirely in the context of the previous report. Basically, the correction is applied from the comparison of the predicted average dilution versus the observed minimum dilution in the spreading layer as indicated in Fig. 6 of the report. In the report by Peter Mangarella, the field data have been reported as minimum dilutions, and all subsequent interpretation is made on this basis. As reported, the laboratory data indicate the ratio between average and minimum dilution within the spreading layer to be about 1.28 for two dimensional flows. Therefore the ratios of the predicted to observed dilutions are reduced by a factor of 1.28 to convert the dilutions from average to minimum. Since the laboratory data are for round buoyant jets, it is not obvious that the scaling between these and the diffuser results is direct. However, in the absence of better information, this approach is taken herein. A linear regression to fit (in a least squares sense) a cubic polynomial to the ratio of observed to predicted minimum dilution was performed on all the data presented in Fig. 6. The result of this regression analysis is

$$\mathbf{CORRECTION = 0.8913 - 0.01996\,\eta + 0.005518\,\eta^2 - 0.0001927\,\eta^3}$$

where $\eta = l_m/l_b$ as defined in the previous report. The variation of the correction function is fairly small with the standard error of estimate only slightly less than the standard deviation of the uncorrelated data (0.142 versus 0.162) The report by Mangarella (hereafter referred to as the Woodward Clyde report) provides estimates for the same parameter from the various field data cases with a fairly minor range of variation between 1.49 and 4.63. A correction following the above regression equation was applied to the predictions provided in the Woodward Clyde report. There is one cast that grossly deviates from the predictions. That is Cast 42 and the observed minimum dilution was measured directly above the diffuser. Since the observed and predicted minimum dilution are off by a factor of 3 and inconsistent with the previous Cast 41 which has nearly the same conditions, this particular data set is excluded from further consideration. The average of the remaining corrected predicted to observed minimum dilutions is 1.019 with a standard deviation of 0.255. The exact results are presented in Table 4. A closer inspection appears to indicate that the ratio of predicted to observed dilution is still a decreasing function of l_m/l_b, but this could be due to other influences since that ratio increases with time through the field study period. It is unlikely that a more satisfactory correction can be attained because the remaining deviation is probably attributable to uncertainties in the field data acquisition effort.

MARCH 1986 DATA

The interpretation of this data is complicated by several factors. One of the most important difficulties is that the plume is predicted to be submerged during the early phases of the field study while the observations indicate a surfacing plume. This is consistent with the previous observation that UDKHDEN uses too large of an entrainment coefficient and thus considerably under-predicts the maximum rise height. It is extremely difficult to develop a simple correction for this portion of the data since the correction mentioned above takes no account of the problems with the incorrectly predicted maximum rise height and doesn't matter since the plume in October was always submerged. If one takes the average of the ratios of predicted and observed dilutions for the case where the plume is predicted to be submerged but is observed to have surfaced, the average is 0.997 with a standard deviation of 0.387. Therefore, it is unlikely that a much more satisfactory correction procedure can be developed and such an effort was not attempted.

Towards the end of the field study, both model predictions and field study indicate the plume to be submerged. However, there are only two measurements during this period. The exact values of the ratio l_m/l_b are not presented in the Woodward Clyde report but an estimate was developed. In both of these cases, the minimum observed dilution was directly above the diffuser and was between 55-60 percent of the predicted dilution. In both of the October casts where the minimum dilution was measured directly above the source, similar discrepancies are found. Since the laboratory data records minimum dilution at a horizontal location approximately one maximum rise height away from the discharge, it is not obvious that these types of measurements should correspond to the recommended corrections. Therefore these two observations are not considered further because of an insufficient sample size and because of basic questions as to whether they should be interpreted as equivalent to the other data.

This leaves the data which were observed to surface and which were also predicted to do so. Actually, one data set which was predicted to stop rising only 2 m below the water surface (Cast 125) is included in this set. For the interpretation of this data, a differentiation was made between data where the minimum dilution was found at Station 33 (directly above the diffuser) or elsewhere. For the former case, the predicted dilution was adjusted downward by a factor of 0.835 (since the dilution in a two dimensional plume is linear with distance) to account for the surface blocking layer as discussed in Wright, 1985, i.e.

$$\mathbf{S_{min}\ (corrected) = 0.835\ S_{min}\ (predicted)}$$

For all other stations, the effect of the near field density jump is included in the analysis by increasing the corrected dilution by an additional 13 percent, i.e.

$$\mathbf{S_{min}\ (corrected) = 0.835 \times 1.13\ S_{min}\ (predicted) = 0.94\ S_{min}\ (predicted)}$$

For all the data in this set, there are several observations that are quite far off the predicted dilutions. The results are tabulated in Table 5. Discarding the four of the twelve that are off by more than 60 percent, the average ratio of corrected predicted to observed minimum dilution is 1.014 with a standard deviation of 0.232. All twelve give an average ratio of 1.20 with a standard deviation of 0.546. There is no obvious explanation for the three or four observations that are off by nearly a factor of 2, but it is not clear that they should be considered in the interpretation of the results as one prediction is too low and the others too high. Of these 4, three are at station 33 and two have much higher predicted than observed dilution. If the remaining eight observations are analyzed, those at station 33 yield an average of predicted to observed dilution of 1.04 (2 observations) and those at all other stations 1.013 (6 observations). Therefore, the correction procedure appears to be rational and has a reasonable theoretical basis.

The one problem that is not addressed in this correction effort is the question of the entrainment coefficient in the UDKHDEN model. Since the entrainment coefficient has been apparently optimized for predicting two dimensional plumes, it is reasonable to expect that it should be more or less satisfactory for the present analysis, since the model predictions show the diffuser jets to be merged by the time they reach the surface and the $\mathbf{l_m/H}$ ratios show the flow to be buoyancy dominated. A computation of the predicted minimum dilution by using the two dimensional plume formula with an appropriate estimate of the entrainment coefficient seems to reproduce the predicted dilutions (before correction) satisfactorily, so it is presumed that this is not a major problem for the surfacing plumes. However, for the plumes that are trapped by the stratification at lower elevations, this may not be the case. Also in other applications where the jets are not fully merged, the same conclusion would be appropriate.

SUMMARY

A series of corrections have been applied to the UDKHDEN plume model based upon observations in laboratory experiments and/or theoretical arguments. The corrections for the case of submerged jets were based upon the observed deviations between vertical round buoyant jets with a correction to transfer from average to minimum dilution. This is subject to several questionable assumptions, but seems to be quite satisfactory in its application. The results for surfacing jets is based upon a theoretical model that is supported by a considerable amount of other data. Within the scatter in the field data, the corrected model predictions quite satisfactorily reproduce the field observations. Unless specific causes for the deviations between the predictions and observations can be determined, it is unlikely that more accurate corrections can be developed.

TABLE 4. Summary of Results from October, 1985 Field Survey.

Cast	Station	l_m/l_b	$S_{observed}$	$S_{predicted}$	$S_{pred.}$ (corrected)	Ratio (corr./obs.)
6	33	2.12	46	42	37	0.80
7	34	2.06	37	56	49	1.32
8	45	1.90	45	56	49	1.09
9	42	1.90	42	56	49	1.17
12	43	2.03	50	65	57	1.14
15	43	1.78	97	90	78	0.80
26	42	1.66	49	58	51	1.04
27	32	1.49	53	73	64	1.21
41	43	1.76	92	105	92	1.0
42	33	1.68	33	105		X
53	43	2.90	34	60	53	1.56
54	42	2.75	69	60	52	0.75
55	42	3.21	72	75	66	0.92
82	42	3.45	59	41	55	0.76
93	44	4.63	94	59	53	0.56
113	42	3.77	64	91	80	1.25
114	42	4.00	81	86	76	0.94
					Mean	**1.019**

TABLE 5. Summary of Results from March, 1986 Field Survey.

Cast	Station	Submerged Observed	Pred.	$S_{observed}$	$S_{predicted}$	$S_{pred.}$ (corrected)	Ratio (corr./obs.)
4	33	N	Y	200	191		X
5	32	N	Y	220	176		X
6	42	N	Y	260	224		X
11	42	N	Y	211	269		X
12	42	N	Y	295	262		X
15	33	N	Y	148	252		X
33	33	N	N	421	205	172	0.41X
42	42	N	N	148	300	282	1.91X
43	32	N	N	197	236	222	1.13
44	32	N	N	219	236	222	1.01
45	33	N	N	184	236	197	1.07
46	33	N	N	140	162	135	0.96
66	33	N	N	91	257	214	2.35X
67	43	N	N	246	239	225	0.91
93	33	N	N	85	360	300	1.62X
125	44	N	N*	236	234	220	0.93
126	42	N	N	197	135	127	0.64
127	43	N	N	118	183	172	1.46
144	33	Y	Y	140	272	240?	X
169	33	Y	Y	84	183	161?	X
					Mean	**(excluding X)**	**1.014**
						all	**1.20**

Notes: * - predicted to rise to within 2 m of surface
? - exact l_m/l_b values unknown

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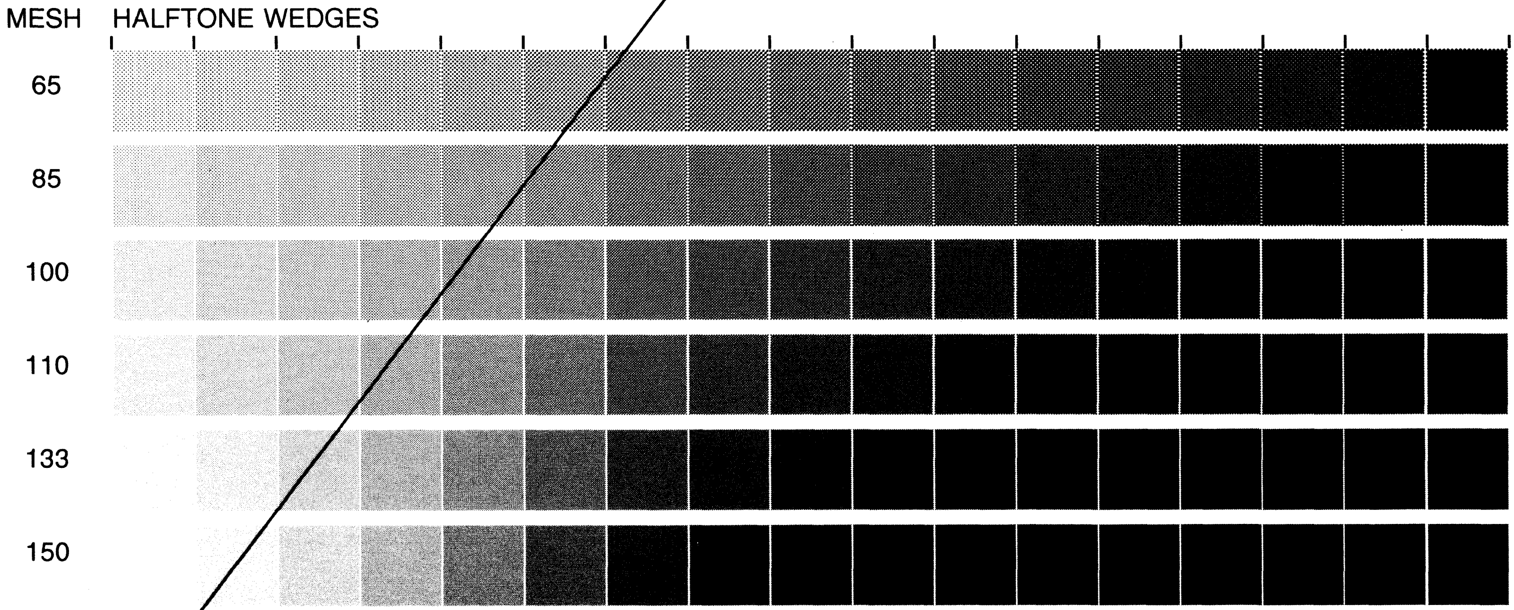

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