Population-Based Surveillance and Etiological Research of Adverse Reproductive Outcomes and Toxic Wastes

PHASE IV-A

Public Drinking Water Contamination and Birthweight, Fetal Deaths, and Birth Defects

NEW JERSEY DEPARTMENT OF HEALTH

A BETTER STATE OF HEALTH

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POPULATION-BASED SURVEILLANCE AND ETIOLOGICAL RESEARCH OF ADVERSE REPRODUCTIVE OUTCOMES AND TOXIC WASTES

EXECUTIVE SUMMARY

November 1992

New Jersey Department of Health

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Project Officer: Larry D. Edmonds
Division of Birth Defects and Developmental Disabilities
National Center for Environmental Health and Injury Control
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The principal authors wish to express gratitude to many people for enabling the completion of this multi-year project and its five reports.

We were very fortunate to have a dedicated staff who contributed to the project over a long period of time: many of these individuals continue to work at the Department, continuing to contribute toward the project's objectives:

> Jorge Esmart, Ellen Dufficy, Marian McElroy, Kay Knoblauch, Barbara Guidici, Debra Dragnosky-Embert, Suzanne Tschachler, and Donna France conducted interviews of the cases and controls; Jorge Esmart, Ellen Dufficy and Mary Knapp compiled, completed, and cleaned the birth outcomes data.
>
> Carmen Pedroza and Jeanette Corbin contributed their secretarial and data entry skills.

Numerous Departmental personnel supported the project through its many phases:

> Elizabeth Shapiro, Pamela Costa and Barbara Kern supported the project through their work on the Birth Defects Registry. Jonathan Savrin assisted in the completion of the reports. Perry Cohn, William Coniglio and Jerald Fagliano contributed technical insights. George Halpin, Susan Lenox-Goldman, Jerald Fagliano, Kathleen Cunningham, Diana Kiel, James Brownlee, Rebecca Zagraniski, and Leah Ziskin provided management support and technical reviews.

This project depended for its success on cooperation and contributions by many individuals outside the Department of Health:

> Barker Hamill and his staff in the Bureau of Safe Drinking Water made it possible to conduct the exposure assessment for the drinking water studies. Robert Tucker and Leslie McGeorge of the Division of Science and Research coordinated the technical reviews and communications within Department of Environmental Protection and Energy. Our able Peer Review Panel was composed of Drs. Howard Kipen, Dirk Moore, Nigel Paneth, and Sherry Selevan. We thank the water companies of northern New Jersey for their consistent cooperation. We are indebted to the hundreds of New Jersey women who shared their time and life experiences with us.

Lastly, this project succeeded because of the constant and creative support of our project officer, Larry Edmonds of the Centers for Disease Control.

POPULATION-BASED SURVEILLANCE AND ETIOLOGICAL RESEARCH OF ADVERSE REPRODUCTIVE OUTCOMES AND TOXIC WASTES

REPORT ON PHASE IV-A: PUBLIC DRINKING WATER CONTAMINATION AND BIRTHWEIGHT, FETAL DEATHS, AND BIRTH DEFECTS

A CROSS-SECTIONAL STUDY

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April, 1992

New Jersey Department of Health

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EXECUTIVE SUMMARY

This report is part of a multi-year cooperative agreement between the New Jersey Department of Health and the Centers for Disease Control, entitled Population-based Surveillance and Etiologic Research of Adverse Reproductive Outcomes and Toxic Wastes. Under Phase IV of the overall project, two individual-based studies were conducted utilizing the environmental databases which were identified in Phase II as the most appropriate for this purpose: i.e., the database for the drinking water sampling of public systems established in 1984 under the New Jersey "A-280" statute and the databases on monitoring of inorganics and trihalomethanes for public water systems. Vital records and the New Jersey Birth Defects Registry were utilized to ascertain individual subjects.

The studies focused on four counties in northern New Jersey. These counties were not selected based on their rates of adverse reproductive outcomes, but rather, were chosen because they were among the five counties in the state with the highest number of public drinking water samples detecting one or more "A-280" contaminants during the first year of the A-280 program. In addition, a high percentage of the population in these four counties were served by relatively well-defined public water systems, including systems utilizing groundwater alone, surface water alone, or a mixture of the two, thus offering a variety of contamination situations (i.e. no detected contaminants, trihalomethanes only, one or more "A-280" contaminants only, or both types of contaminants detected.)

Since no data were available on private well contamination, towns in these four counties which had greater than 20% of their population on private wells were excluded from these studies. In addition, since birth certificate information was incomplete for those born in out-of-state hospitals, towns with 10% or more of their births born out-of-state (such as in New York City), were also excluded. Out of a total of 146 towns in these four counties, 75 were selected for these two studies.

The design of the study described in this report was "cross-sectional" because the entire study population was used (there was no sampling of subjects). In addition, no interviews were conducted, so that residential data obtained from the birth or fetal death certificates were used to represent residency for the time periods of interest, i.e. the entire pregnancy and the first trimester. Sociodemographic and outcome data were

obtained from the birth certificates, fetal death certificates, and New Jersey Birth Defects Registry forms only. Therefore, information on drinking water habits, exposure to other potential risk factors such as occupational exposures, smoking, and medications taken during pregnancy, could not be taken into account in the analyses. However, information on some potential risk factors, such as the number of prenatal visits, maternal age, race and education, parity, and previous pregnancy loss, were obtained from the birth certificate or fetal death certificates.

Information on the birth certificates were used to determine birthweight and gestational age. Causes of fetal death were obtained from that certificate. The birth defects diagnoses for livebirths were provided by the Birth Defects Registry. The outcomes evaluated included birthweight among term births (as a continuous variable), low birthweight (< 2500 grams) among "term" births (259-293 days gestational age), very low birthweight (< 1500 grams), small-for gestational age (tenth percentile of weight, race and sex specific, by gestational week), prematurity (<37 weeks gestational age), fetal deaths, all birth defects usually included in surveillance, and selected birth defects categories.

The study period was January 1, 1985 - December 31, 1988, the four years commencing when the Birth Defects Registry was initiated and the New Jersey drinking water monitoring statute took effect. The study population was all singleton births and fetal deaths during the study period. For each birth and fetal death, exposure to drinking water contamination for each gestational month of the pregnancy was estimated by using the sample data for the drinking water system serving the municipality of maternal residence at birth (or death of the fetus). The estimation process was performed without knowledge of the outcome status of the study subjects. Data on approximately 80,000 subjects were analyzed in this study.

The contaminants in drinking water of interest were total trihalomethanes (TTHM), the total amount of 14 volatile organics (TVOC) tested by NJDEPE's A-280 program, and specific 'A-280" contaminants: trichloroethylene (TCE), tetrachloroethylene or "perchloroethylene" (PCE), the dichloroethylenes (DCE), 1,1,1-trichloroethane (TCA), carbon tetrachloride (CTC), 1,2-dichloroethane or "ethylene dichloride" (EDC), and benzene. In addition, nitrates and the source of drinking water (groundwater surface water, or a mixture of the two) were evaluated.

After adjustment for potential risk factors, TTHM and surface water source were associated with decreased birthweight. At TTHM concentrations exceeding the MCL of 100 ppb, the average decrease in birthweight was 70 grams, while the average decrease in birthweight for exposure to surface water source was 31 grams. Although in the initial adjusted analyses TCE, benzene, and nitrates were found to be associated with increasing birthweight, in subsequent analyses, these findings were found to be due to the confounding effects of TTHM and the associations disappeared when TTHM was included in the analyses.

CTC (>1 ppb) was found to be associated with increased prevalence of term low birthweight with an odds ratio (OR) of 2.26. Surface water source and TTHM (> 80 ppb) were also associated with increased term low birthweight (OR = 1.35). A less precise association (i.e. the 95% confidence interval included the OR of 1.0 and the one tail p value was less than 0.05) was found for increased term low birthweight with a mixture of water sources (OR = 1.17).

The results of the analyses of "small for gestational age" (SGA) were similar to the term low birthweight results, but the odds ratios were reduced. CTC (>1 ppb, OR = 1.35), surface water source (OR = 1.22) and TTHM (> 80 ppb, OR = 1.22) were associated with increased prevalence of SGA. In the initial analyses, TVOC, PCE, TCA, and nitrates were associated with a decreased prevalence of SGA, but these associations disappeared after adjustment was made for the confounding effects of TTHM.

Surface water source was associated with an increased prevalence of premature birth (OR = 1.12). A less precise association was found for TTHM (>80 ppb, OR = 1.09). On the other hand, nitrates (> 2 ppm) were associated with a decreased prevalence of premature birth (OR = 0.84). Only surface water source was associated with an increased prevalence of very low birthweight (OR = 1.17), while nitrates and detected benzene were associated with decreased prevalence. These findings indicated that the drinking water contaminants evaluated in this study had little if any relation to the prevalence of premature birth or very low birthweight.

Surface water source was associated with an increased prevalence of stillbirths (OR = 1.37). No other exposure was associated with increased prevalence of stillbirths. After adjusting for the confounding effects of surface water source, findings of decreased stillbirth prevalence for nitrates and EDC disappeared. In the adjusted analysis of benzene, a less precise association was found with decreased stillbirth, but this association was an artifact of the exclusion of study subjects who had missing values for one or more of the risk factors included in the adjustment.

TTHM (> 80 ppb, OR = 1.58) and surface water source (OR = 1.31) were associated with an increased prevalence of all surveillance congenital anomalies. No other exposure was associated with increased prevalence. After adjusting for the confounding effects of TTHM, findings of decreased prevalence of congenital anomalies associated with TVOC and TCA disappeared.

CTC (> 1 ppb, OR = 3.80), DCE (>2 ppb, OR = 2.52) and TTHM (> 80 ppb, OR = 2.60) were associated with an increased prevalence of central nervous system (CNS) defects. A less precise association was found with TCE (> 10 ppb, OR = 3.24) and multiple CNS defects, but TCE was not associated with either single or combined CNS outcomes. After adjustment for the confounding effects of TTHM, and other risk factors, a less precise association was found with nitrates (> 2ppm) and CNS defects (OR = 1.77).

CTC (> 1 ppb, OR = 5.39) and TTHM (> 80 ppb, OR = 2.98) were associated with an increased prevalence of neural tube defects (NTD) - a subgroup of CNS defects. Less precise associations were found with TCE (> 10 ppb, OR = 2.53), DCE (>2 ppb, OR = 2.60), nitrates (>2 ppm, OR - 1.82) and mixed water source (OR = 2.34). After adjustment for the confounding effects of TTHM, the association with nitrates became stronger (OR = 2.72, 95% confidence interval = 1.3 - 5.6). An association was found for TVOC and multiple NTD cases (> 1 ppb, OR = 5.13) but not for single NTD cases or for the combined NTD outcome.

TCE (>5 ppb, OR = 2.24) and PCE (>10 ppb, OR = 3.54) were associated with an increased prevalence of <u>oral cleft defects</u>. A less precise association was found with CTC (>1 ppb, OR = 3.60). A less precise association with cleft lip only was also found for TVOC (> 5 ppb, OR = 1.76), but TVOC was not associated with cleft palate or with the combined oral cleft outcome.

Detected amounts of EDC was associated with an increased prevalence of <u>major cardiac defects</u>. An elevated prevalence (OR = 2.11) was also seen at EDC levels above 1 ppb but was not statistically significant. Less precise associations were found with TTHM (> 80 ppb, OR = 1.84) and surface water source (OR = 1.54). Less precise association with <u>all cardiac defects combined</u> were found for TTHM (>80 ppb, OR = 1.44) and surface water source (OR = 1.41). No contaminants were associated with <u>ventricular septal defect only</u>. TCA was found to be associated with a decreased prevalence of major cardiac defects. This association did not disappear with adjustment by TTHM or by surface water source, but initial associations between decreased prevalence of all cardiac defects combined with the contaminants TVOC, PCE, DCE, TCE, and nitrates did disappear after adjustment for the confounding effects of TTHM or surface water source.

The above findings should be interpreted cautiously: 1) exposure misclassification could lead to underestimation of effects, 2) unmeasured confounding could introduce bias leading to underestimation or overestimation of effects of exposure, and 3) associations could be chance occurrences. In themselves, the positive associations found in this study <u>do not</u> provide sufficient evidence to make the claim that these contaminants <u>cause</u> adverse reproductive outcomes at the levels commonly found in public drinking water systems, and the scarcity of other toxicological and epidemiologic research on the reproductive effects of these drinking water contaminants prevents us from making such claims. Further, the findings of this study <u>do not</u> imply that pregnant women or women considering pregnancy should drink only bottled water; exposures to the contaminants in the study while bathing or showering can be at least as high as exposures through drinking water, and it cannot be assumed that bottled water has lower concentrations than tap water of the contaminants studied. Nor do the study findings indicate that citizens should install household filtering systems, particularly since such systems tend to be expensive and require regular maintenance.

Nevertheless, from a public health perspective, the above associations should be taken seriously and investigated further. The findings of this study support continued and enhanced vigilance on the part of USEPA and states to enforce the regulations of the federal Safe Drinking Water and the Clean Water Acts and the analogous state laws. The study findings also support the development of new technologies and practices designed to reduce or eliminate the concentrations of these contaminants in drinking water.

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PUBLIC DRINKING WATER CONTAMINATION AND BIRTHWEIGHT, FETAL DEATHS, AND BIRTH DEFECTS: A CROSS-SECTIONAL STUDY

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1.0 INTRODUCTION

There is considerable public health concern in New Jersey (NJ) about the quality of drinking water. Several community supplies have been designated as "Superfund" (National Priority List) sites including those in Rockaway Boro, Rockaway Township, and Dover Town in Morris County, and Lodi Boro and Fair Lawn Boro in Bergen County. In 1984, state legislation (Assembly Bill A-280) was enacted establishing routine, semi-annual testing of community water supplies for fourteen volatile organics such as trichloroethylene (TCE), tetrachloroethylene (PCE) and 1,1,1-trichloroethane (TCA). The initial state-wide sampling in late 1984 found that 18% (101) of 630 community supplies had detectable amounts (≥ 0.5 ppb) of one or more of the fourteen contaminants (NJDEP, 1986). A similar percentage of contaminated supplies were found during the routine testing in 1985 (NJDEP, 1987). TCE, PCE and TCA were the most frequently detected contaminants in the initial and 1985 samples.

The NJ Department of Health (NJDOH) has participated in a Cooperative Agreement with the Centers for Disease Control (CDC) to study the possible relationships between population exposures to environmental pollutants and adverse reproductive outcomes.

As part of this project, NJDOH performed epidemiologic studies examining the possible relationships between exposure to contaminants in community drinking water and increased risks for selected adverse reproductive outcomes.

1.1 ANIMAL STUDIES

Volatile organics (VOCs) detected in several drinking water supplies in NJ include benzene, 1,1,1-trichloroethane (TCA), tri-chloroethylene (TCE) and perchloroethylene (PCE) which have been found to be associated with birth defects or low birthweight in animal studies. For example, Shepard's Catalog of Teratogenic Agents reported that: 1) benzene was associated with cleft palate in mice and fetal growth retardation and skeletal anomalies in rats, 2) TCE was associated with anomalies of skeletal and soft tissues indicative of developmental delay in rats, and 3) TCA was found to reduce fetal weight in rats (Shepard, 1986). Inhalation of PCE was associated with increased fetal resorptions in rats and decreased fetal body weight in mice (Van der Gulden and Zielhuis, 1989). TCE administered to chick embryos has been associated with an increased number of malformations, resorptions and embryonic deaths (Loeber et al., 1988); in this study, the chick embryos exposed to TCE had over three times the rate of cardiac deformities as the unexposed embryos. A later study found that TCE and 1,1-dichloroethylene were associated with increased cardiac defects in rats (Dawson et al., 1990).

To date, there is no evidence from animal studies that chloroform, other trihalomethanes, or nitrates have adverse effects on reproduction.

1.2 HUMAN STUDIES: OCCUPATIONAL AND COMMUNITY EXPOSURES

Associations between low birthweight and possible population exposures to VOCs have been found at toxic waste sites such as Love Canal (Vianna and Polan, 1984) and the Lipari Landfill in NJ (NJDOH, 1989).

Studies in Finland have implicated maternal exposure to organic solvents at the workplace and/or at home with elevations of birth defects of the central nervous system (odds ratio, OR, = 5.5, $p < .025$; Holmberg et al., 1980), oral clefts (OR = 3.5, $p < .05$; Holmberg and Nurminen, 1982) and cardiovascular system, (OR for ventricular septal defect = 1.5, 95% Confidence Interval, CI, = 1.0 - 3.7; Tikkanen and Heinonen, 1988). In a study of maternal work exposures to PCE and other solvents in dry cleaning shops, PCE was not found to be associated with low birthweight or birth defects, but the "handling of other solvents" (spot removers, acetone) was associated with birth defects (OR = 5.9, 95% CI = 1.0 - 35.7; Kyyronen et al., 1989).

All the above studies suffered from a lack of data on actual chemical exposures and on potential confounding factors. The occupational studies in particular had inadequate sample sizes. Given these limitations, the findings are suggestive and warrant further study.

1.21 EXPOSURES TO DRINKING WATER CONTAMINATED WITH VOCs

Studies of adverse reproductive outcomes among those exposed to drinking water supplies contaminated with VOCs in Woburn, Massachusetts (Lagakos et al., 1986a), Battle Creek, Michigan (Freni and Bloomer, 1988), Santa Clara County, California (Wrensch et al., 1990; Swan et al., 1989; CADOHS, 1985) and Tucson, Arizona (Goldberg et al., 1990) have produced conflicting results. These are each described below and summarized in Table 1.

In the Woburn Study, exposure to drinking water from public wells contaminated with TCE (267 ppb), PCE (21 ppb) and dichloroethylenes (28 ppb) was associated with a statistically significant increased risk of perinatal mortality. Among the 17 perinatal deaths, 4 were exposed, most of whom were stillbirths of mothers estimated to be among the most highly exposed (OR = 10.0 for the highest exposure level).

The Woburn researchers created five groupings of birth defects: musculoskeletal anomalies, cardiovascular anomalies, eye and ear anomalies, central nervous system, chromosomal and oral cleft anomalies and "other anomalies". The mixing of diseases with diverse etiologies within each of these broad groupings would tend to underestimate risk which may have contributed to the lack of observed associations between exposure and musculoskeletal, cardiovascular and "other anomalies". However, statistically significant associations were found between drinking water exposure and two of the birth defect groupings - eye and ear anomalies (OR = 14.9 for the highest exposure level among eye defects) and central nervous system, chromosomal and oral cleft anomalies. The latter association was primarily central nervous system defects (OR = 2.3 for the highest exposure level) and chromosomal defects.

Although the associations found in Woburn suggest an effect of the contamination on reproductive outcomes that should be followed up in other studies, the study was seriously limited by small numbers of cases and by the analytic approach of combining diseases with diverse mechanisms and etiologies into broad categories. Other reviewers of the Woburn study have suggested other deficiencies such as low response rate, strong opportunity for response bias and poor information quality (MacMahon, 1986). MacMahon especially criticized the study for the use of volunteers from the community to perform the phone interviews that provided the data on adverse reproductive outcomes. However, according to the authors of the Woburn study, there was no evidence for differential bias from the use of volunteers, from recall of the interviewees, or from the low response rate (Lagakos et al., 1986b).

A study of private well contamination in the Battle Creek Michigan area evaluated birth defects, low birthweight, stillbirths, prematurity and miscarriage. No associations were found between these outcomes and exposure to VOCs such as TCE, PCE and 1,1-dichloroethylene in the wells. However, the very small number of cases included in the analysis for stillbirths (N=2), low birthweight (N=11) and prematurity (N=7) make interpretation of these findings difficult. Of the 11 birth defects included in the analysis, only one was exposed to VOCs other than chloroform. Defects with diverse etiologies were combined. Although the rate of miscarriage was twice as high in the contaminated area as in the unexposed reference area (based on a total of 88 cases), after exclusions and a more refined estimate of exposure, no association was found (based on 23 cases). No effort was made to examine the effects of exposure separately by trimester. In summary, this study has too many limitations for its results to contribute significantly to the weight of evidence regarding VOCs in drinking water and adverse reproductive outcomes.

In Santa Clara County, a census tract containing a contaminated public well (1.7 ppm TCA) had a statistically significant increased rate of birth defects compared to an unexposed census tract (OR = 4.3, 95% CI = 1.2 - 14.7; Wrensch et al., 1990). No association was found for low birthweight. However, modeling the water distribution from the contaminated well revealed that another census tract actually received most of its water. No positive associations were found for spontaneous abortions or birth defects for this tract, but the prevalence of low birthweight was elevated (OR = 1.7, 95% CI = 0.5 - 6.0).

A greater than twofold excess prevalence of serious cardiac anomalies was found in the service area of the water company (Swan et al., 1989). However, the spatio-temporal pattern of cardiac defects in the service area did not fit the modeled distribution of water from the contaminated well or the timing of the potential exposure from the well. The investigators concluded: "The evidence does not support the contamination from Well 13 as the cause of this cluster." The authors could not account for the cluster in their investigation. In an earlier report on the studies in Santa Clara County (CADOHS, 1985), the authors had stated: "...this study found some evidence to suggest that case mothers were somewhat more likely to have had TCA exposure from their drinking water than control mothers at a time period in gestation critical for cardiac development." This conclusion was also based on the modeling of the distribution system although only six cases could be assigned an exposure score.

Recently, a study of drinking water in the Tucson Valley area of Arizona reported that mothers residing in areas supplied by water contaminated with TCE (from 6 ppb to 239 ppb), 1,1-dichloroethylene (between 5% and 10% of the TCE levels) and chromium (no levels given) had a threefold greater prevalence of cardiac defect children than mothers residing in areas supplied by uncontaminated water (Goldberg et al., 1990). The study was sparked by an informal review in 1973 of the address zipcodes of children with cardiac defects. This review found that 1/3 of the cases came from a small area in the southwestern part of the city of Tucson delineated by two zipcodes. In 1981, most of this area was found to be served by the contaminated drinking water.

The study identified all children born in Tucson Valley from 1969 through 1987 with cardiac defects (excluded were those with recognized syndromes, premature infants with patent ductus arteriosus, newborns with peripheral pulmonary stenosis and patients with bicuspid aortic valve without stenosis or regurgitation) whose parents lived in the Valley immediately before and during the pregnancy. Cases were interviewed by phone to determine residence and workplace during pregnancy. One control group was constructed by taking a random sample of phone numbers in the Tucson Valley. A second control group was constructed by taking a sample of phone numbers frequency matched to cases by telephone prefixes. For each selected phone number, the answering individual was asked if any household members ever worked or lived in the contaminated area. In other words, all members of the immediate family were included in the control group. The threefold greater prevalence result was based on a comparison of cases with either control group. However, the exposure was defined as "contact with the contaminated water area" regardless of whether the contact (through residence or workplace) during pregnancy came before or after the contaminated wellfield was closed.

Another comparison was made between the contaminated and uncontaminated areas using vital records to determine the number of births occurring in each area. In the contaminated area, 74 cardiac cases were born to mothers who resided in the area prior to the closing of the wellfield during the first trimester. During this period, there were 10,907 total livebirths for a prevalence of 6.8 per 1,000. Although this prevalence was consistent with prevalences reported in the literature (about 7 per 1000), it was over 2.5 times the prevalence in the uncontaminated area (2.64 per 1000).

Based on the above description, neither control group was appropriate for determining the prevalence of exposure among mothers of livebirths in Tucson Valley since all household members were included, including those who could not have given birth. In addition, potential confounders were not properly taken into account. Interpretation of the study is further hampered by problems in study description (e.g. the cases disappear without explanation, unexposed cases are labeled a "control group", tables do not appear to agree, and information on exposure for controls is lacking.)

In summary, further study of the possible relationship between VOC-contaminated drinking water and adverse reproductive outcomes is needed because of conflicting findings and limitations of the above studies, particularly the small sample sizes, the grouping of diseases with various etiologies, the questionable exposure assessments, and other study design limitations.

1.22 EXPOSURES TO DRINKING WATER CONTAMINATED WITH TOTAL TRIHALOMETHANES (TTHM)

A study of trihalomethanes in public drinking water systems and intrauterine growth retardation (IUGR), prematurity and low birthweight was conducted in Iowa (Kramer et al., 1992). No association was found for prematurity or low birthweight, but increased risk (OR = 1.8, 95% confidence interval = 1.1, 2.9) of IUGR was found at chloroform levels equal to or above 10 ppb.

1.23 EXPOSURES TO DRINKING WATER CONTAMINATED WITH INORGANICS

A study in Massachusetts of cardiac defects and inorganic contamination of public water supplies found weakly positive associations that were not statistically significant for some metals (e.g., mercury, lead and nitrates) based on the analysis of 270 cases (Zierler et al., 1988). When specific defects were evaluated, a statistically significant association was found between arsenic and coarctation of the aorta (OR = 3.4, 95% CI = 1.3 - 8.9).

In another study (Aschengrau et al., 1989), slightly positive associations that were not statistically significant were found between spontaneous abortion and some metals (e.g., mercury and arsenic). In addition, statistically significant associations were found between spontaneous abortion and potassium (OR = 2.6), silica (OR = 1.9), water hardness (OR = 2.9) and surface water source (OR = 2.2).

A study of public system and private well drinking water supplies in South Australia evaluated the relationship between nitrate levels and congenital malformations (Dorsch et al., 1984). A statistically significant dose-response relationship was found between nitrate level in drinking water and the risk of having a child with a birth defect. Statistically significant associations were found between maternal consumption of groundwater contaminated with nitrates and neural tube (OR = 3.5) and oral cleft (OR = 4.0) anomalies.

A study of central nervous system defects and nitrate levels in public water systems and private wells in New Brunswick, Canada, found a positive association (OR = 2.3) that was not statistically significant for the higher stratum (87.5 percentile for nitrate levels, mean = 26 ppm) in private wells when compared to the baseline stratum (nitrates, < 0.1 ppm) (Arbuckle et al., 1988), but the power of the study was very low. Municipal supplies had relatively low levels of nitrates (virtually all were below the current US Maximum Contaminant Level of 10 ppm) and no association was found.

The difference in the findings from these two nitrate studies may have been due to the relatively low levels of nitrates found in the New Brunswick study. Most of the New Brunswick population were exposed to nitrate levels not exceeding 12 ppm.

1.3 PRESENT STUDY

The New Jersey Department of Health (NJDOH) utilized its population-based birth defects registry and its vital records (birth certificate, infant and fetal death), as well as data obtained from the New Jersey Department of Environmental Protection (NJDEP) on the levels of 14 VOCs (the "A-280" Program), TTHM and nitrates in public water systems, and the type of water source used by these systems (groundwater, surface water or a mixture) to evaluate the relationships between potential residential exposures to contaminated drinking water supplied by public systems and adverse reproductive outcomes.

This report describes the "cross-sectional" (non-interview) study using all births and fetal deaths occurring to mothers who resided at the time of birth in 75 towns in northern New Jersey. A parallel case-control study is described elsewhere (NJDOH, 1992).

1.4 STUDY HYPOTHESES

The <u>categorical</u> outcomes evaluated in this study were (see <u>Table 2</u> for definitions of these outcomes):

low birthweight (< 2500 grams) among term (≥ 259 days) livebirths
small for gestational age (SGA) among livebirths
prematurity (< 259 days) among livebirths
very low birthweight (< 1500 grams) among livebirths
stillbirths (or fetal deaths)
surveillance malformations: 33 selected categories from ICD-9
range 740.0-759.9
all central nervous system defects and subgroupings
all oral cleft defects and subgroupings
all cardiac defects and subgroupings

One <u>continuous</u> outcome was also evaluated: birthweight among "term" (narrowly defined as 259-293 days) livebirths.

The null hypotheses were that these outcomes had no association with estimated exposures during the first trimester (birth defects and stillbirths) or over the entire pregnancy (prematurity and the outcomes related to birthweight) to "A-280" VOCs, TTHM, nitrates, and type of water source.

The "A-280" VOCs evaluated were trichloroethylene (TCE), tetrachloroethylene (PCE), total dichloroethylenes (DCE), 1,1,1-trichloroethane (TCA), carbon tetrachloride (CTC), benzene and 1,2-dichloroethane (EDC). These contaminants were evaluated separately and then were combined to form the variable, "total A-280 volatile organics" (TVOC). Other "A-280" chemicals could not be evaluated because they were detected too infrequently (or not at all) in the study area. Methylene chloride was not evaluated since it is found frequently on method blanks (see Section 2.4).

A total of 143 null hypotheses were formally evaluated in this study: eleven exposures (TVOC, TCE, PCE, DCE, TCA, CTC, EDC, benzene, nitrates, TTHM, type of water source) and thirteen outcomes (birthweight as a continuous variable among "term" births, SGA, term low birthweight, prematurity, very low birthweight, stillbirths, all surveillance anomalies, all CNS defects, neural tube defects, all cardiac defects, major cardiac defects, ventricular septal defect, oral clefts - see Table 2 for definitions of these outcomes). It should be noted that many of these comparisons were not independent since several of the outcomes and some of the exposures were related. Nevertheless, each of the 143 formal comparisons were evaluated separately as if it were the only comparison made in the study (Rothman, 1990). Further discussion of the issue of multiple comparisons appears in section 4.2.

Each exposure variable-outcome relationship was formally observed to evaluate the null hypothesis. **This formal evaluation used the adjusted result unless the unadjusted result was similar using a "15% rule": i.e., the adjusted and unadjusted results differ by no more than 15% (Mickey and Greenland, 1989).** In addition, this formal evaluation used one of the characterizations of each exposure; i.e., the one that produced the highest adverse reproductive effect estimate with some precision as measured by the confidence interval. This position was based on the following: 1) our belief that non-differential exposure misclassification was the major source of bias in the study; 2) the difficulty of interpreting the available water contamination data and the numerous assumptions needed in order to estimate contaminant levels; and 3) a general public health concern that associations worth pursuing should not be missed. (See the Exposure Assessment and Discussion sections for further elaboration.)

In addition to the formal comparisons, other results were presented for informative and exploratory purposes. These included additional characterizations of the exposures, several subgroupings of specific birth defects (i.e., cleft palate, cleft lip with or without cleft palate, single and multiple CNS and neural tube defects) and both unadjusted and adjusted results.

2.0 <u>METHODS</u>

2.1 STUDY AREA

The study area consisted of four contiguous counties in northern NJ. These counties - Bergen, Essex, Morris and Passaic - were selected for the following reasons. First, they were among the five counties in NJ (as of late 1985 when the study was begun) with the highest number of detectable samples of "A-280" contaminants in public water systems (NJDEP, 1987). Second, in addition to numerous small water companies utilizing groundwater supplies, these counties were also served by a few large water systems that utilized surface water supplies. It was presumed that surface water systems would have appreciable levels of TTHM. Therefore, the exposure prevalence of births in the study area to both the "A-280" contaminants and to TTHM was expected to be sufficiently high for good statistical power. Third, unlike many of the other counties in the state, most of the towns in these four counties were served almost entirely by public water rather than private wells for which no data were available. Fourth, the distribution systems of the water companies serving the four counties were less complex than those in other areas of the state. For example, the other county among the top five for "A-280" contamination, Camden, was principally served by a few large water companies utilizing widely scattered wellfields, creating difficulty in determining which wellfield served which town.

Parts of three of the four counties (Bergen, Essex and Passaic) were included in a recent NJDOH study of public drinking water contamination and leukemia (Fagliano et al., 1990) for which NJDOH obtained information from the NJDEP's Bureau of Safe Drinking Water (BSDW) on the water companies serving these counties. In order to increase the sample size of births, the present study built upon this information and the working relationship that had been established between NJDOH and BSDW. The study area was expanded to include more towns in the three counties and to add a fourth county (Morris).

In summary as indicated above, the water companies in the four counties offered a variety of exposure situations. Those utilizing groundwater as their source of supply tended to be uncontaminated or to have VOC contaminants due to industrial spills and discharges or to leaching from landfills. Those utilizing surface water as their source of supply tended to have higher levels of TTHM due to the reactions between the chlorine treated water and organic matter in the water. Finally, some companies utilized both sources of water, usually because "A-280" contaminants were found in their groundwater wells. These "mixed" supplies often contained detectable "A-280" contaminants and TTHM.

Even though all supplies in the study area were chlorinated, the amount of organic matter in the groundwater supplies is insignificant and TTHM levels are therefore near or below the detectable level of 1 ppb. Some companies utilized surface water supplies that were free of "A-280" contaminants but contained relatively higher levels of TTHM. Finally, some companies used a mixture of both supplies that contained relatively high levels of both types of contaminants.

All of the following criteria had to be met for a town's inclusion in the study:

1) The town was within Bergen, Essex, Morris or Passaic counties;

2) Virtually all of the town's population was served by public water (based on information supplied by NJDEP's BSDW).

3) Less than 10% of the town's birth certificates had missing information on birthweight. (Missing data on birthweight were typically found for births which occurred in New York City or Philadelphia).

The selection of particular towns for inclusion in the study was <u>not</u> based on information about adverse reproductive outcome rates or on drinking water contamination levels. The study area itself was not selected based on prior knowledge of an adverse reproductive outcome problem. On the other hand, it was expected that urban areas would have relatively high rates of low birthweight. (All 27 towns in the former leukemia study met the above criteria and were included in this study).

The city of Newark met the selection criteria, but was excluded for the following reasons:

1) Newark had twice as many births per year as the next largest city in the study area, Paterson. Its inclusion would have given the study a primarily urban focus. Although the birth certificates provided information on mother's race, prenatal care visits and parental education, it was felt that this information (while a vast improvement on the use of Census data) was still insufficient to control for socioeconomic and other factors, characteristic of urban centers such as Newark, that affect the risk of adverse reproductive outcomes. In order to account for these factors, a specially designed questionnaire would have to have been administered.

2) Since Newark's water supply came from surface water, the focus of the study would have shifted away from "A-280" contaminants, one of its unique features.

Out of one hundred and forty-six towns in the four counties, seventy-six met the selection criteria and seventy-five towns were included after Newark was excluded. The selected towns provided a balance of urban and suburban communities as well as a variety of types of water supply (groundwater, surface water, mixture). Births per year in each town ranged from 9 to 3,062. Population density ranged from 469 per square mile to 21,962 per square mile with 10 towns having population densities greater than 10,000 per square mile (based on 1980 census). Median household income for each town ranged from $12,000 to $49,500 with 19 towns having a median household income of less than $20,000 (5 towns with a median household income less than $15,000) and 21 towns having a median household income greater than $30,000 (1980 census). According to the 1980 census, the median household income per town averaged (unweighted by population size) over all towns in NJ was approximately $24,600 (median over all NJ towns = $23,260).

2.2 STUDY POPULATION AND TIME PERIOD

The study population consisted of all singleton livebirths and stillbirths identified by NJDOH vital records tapes (birth certificates and fetal death certificates), born during the period January 1, 1985 through December 31, 1988, to NJ residents who at the time of birth resided in the 75 selected towns. Descriptive statistics of some of the demographic information available from birth certificates are given in Table 3. The NJDOH vital records tapes for birth certificates and fetal deaths and the NJDOH population-based Birth Defects Registry (BDR) tape were linked together. Details of the data linkages are discussed elsewhere (Fulcomer et al., 1992). This combined dataset was the sole source of information on outcome status and potential risk factors other than the drinking water exposures of interest. After elimination of duplicate records, the size of the study population over the four-year period was 81,055 singleton livebirths and 599 singleton fetal deaths.

The study period was determined by the availability of data from the NJDOH Birth Defects Registry, whose first complete year of operation was 1985. In addition, the first samples taken under the NJDEP A-280 Program occurred in late 1984.

2.3 OUTCOME VARIABLES

The prevalences in the study area for the categorical adverse reproductive outcomes evaluated in this study are presented in Table 2. An additional outcome evaluated in this study was the continuous variable birthweight. The analysis of the birthweight variable included only livebirths with gestational ages from 37 weeks up to the end of 41 weeks (259 days - 293 days).

Birthweight was converted into grams from pounds and ounces, as recorded on the birth certificates. Livebirths with birthweights recorded on the computer tape that were equal to or less than 500 grams (i.e., ≤ 1 lb, 2 oz) or greater than 5,443 grams (i.e., ≥ 12 lbs) were identified and compared to their hard copy birth certificates to verify the weights and gestational ages.

Based on this review, corrections of birthweights and gestational ages were made to the computer tape. All singleton livebirths who were born in New York City to NJ residents of the 75 selected towns had missing data on birthweight (N = 1,554 or 1.9% of all singleton livebirths). Hard copy birth certificates were not available for these births. Therefore, these births were excluded from the analyses of birthweight, term low birthweight, SGA and very low birthweight. However, these births were eligible for the other study outcomes.

Prematurity was defined as singleton livebirths with gestational ages less than 37 completed weeks as determined from the date of last menses and date of birth specified on the birth certificate. Calculated gestational ages for livebirths that were outside the range of 20 weeks to 50 weeks were considered invalid (Alexander et al., 1990). Subjects with invalid or missing gestational ages (N = 5,158 or 6.4% of singleton livebirths) were excluded from the analysis of prematurity.

Small for gestational age (SGA) was defined as those singleton livebirths that were at or below their race-, sex-, and gestational week-specific tenth percentile weight (Brenner et al., 1976). These tenth percentile norms were calculated for each gestational week (28 weeks - 44 weeks) using birth certificates for all singleton white and black liveborns in NJ during the years 1985-1988 with information on birthweight, date of birth, date of last menses and sex of the child. Due to small numbers, tenth percentile norms were not calculated for livebirths with gestational ages below 28 weeks. Maternal races which were listed on the birth certificate as other than white or black, were categorized as "other". Due to small numbers of births in the "other" race category, the norms for the "other" category were not calculated. The norms for white births were applied to this group as well as to births with missing data on maternal race. Live births with gestational ages less than 28 weeks, with missing (or invalid) data on gestational age, or with missing data on birthweight were excluded from the analysis of SGA.

"Term low birthweight" was defined as singleton livebirths with birthweights less than 2500 grams and with gestational ages of at least 37 completed weeks. Excluded were births with missing data on birthweight or gestational age.

"Very low birthweight" was defined as all singleton livebirths with birthweights less than 1500 grams. Excluded were births with missing data on birthweight.

Stillbirths were identified from the NJDOH fetal death certificate tapes. Most of the stillbirths included in the tape have gestational ages greater than 20 weeks. Most fetal deaths occurring at or before 20 weeks are not issued death certificates and so are not included in this tape. The fetal death certificate tape does not include induced abortions.

Birth defects among livebirths were ascertained using the registrations from the NJ Birth Defects Registry (BDR). Birth defects among stillbirths, in particular anencephalus, were ascertained from the fetal death tape. Included in this study were diagnoses within the range of ICD-9 codes 740.0 to 759.9. Seven groupings of defects were analyzed: 33 selected malformation diagnoses that are usually included in surveillance reports ("surveillance anomalies"), all central nervous system (CNS) defects, neural tube defects, all cardiac defects, "major" cardiac defects, ventricular septal defect, and oral clefts (see Table 2 for definitions).

Chromosomal anomalies (ICD-9: 758.0 - 758.9) were identified using the BDR registrations and the fetal death tape. These births were excluded from the study.

A "control group" was established for the analyses of the categorical outcomes. It consisted of all singleton livebirths who were not SGA or low birthweight, who were not registered as having a birth defect, who were not missing birth certificate information on gestational age or birthweight, and whose gestational age was at least 37 weeks and less than 42 weeks. After these exclusions, 52,483 births remained. Of these, 138 had missing data on mother's race and 11 more had birthweights recorded above 12 lbs. These 149 births were also excluded, leaving a total of 52,334 births in the control group.

2.4 EXPOSURE ASSESSMENT

Information on the water company serving each municipality was obtained from NJDEP's BSDW and, when necessary due to the complexity of the system, from the company itself. All estimates of contaminant levels were performed by one researcher who was blind to the rates for each municipality of the outcomes under study. Descriptive statistics of the drinking water exposure variables are presented in Table 4.

In most cases, a town was served by one company. A few towns were served by more than one company. In almost all of these cases, one company would serve over 95% of a particular town's population, so the additional companies serving the town were ignored in the exposure assessment. Two towns had both a major (> 50%) and a minor (30%-40%) supplier. In order to assess exposures in these two towns, a weighted (by the proportion of the town served) average of the estimated contamination levels in each company's system was taken. Data from a total of 49 water companies were used to estimate monthly drinking water exposures in the 75 towns.

2.41 "A-280" VOLATILE ORGANICS

Data on the levels of VOCs in public drinking water supplies were obtained from the BSDW's A-280 Program. The A-280 Program requires all public water companies to sample their distribution systems (i.e., a tap water sample) at least twice annually and to submit these samples to NJDEP-certified laboratories for analysis of 14 volatile organics (TCE, PCE, TCA, CTC, EDC, benzene, trans-1,2-dichloroethylene, 1,1-dichloroethylene, methylene chloride, xylenes, vinyl chloride, trichlorobenzenes, 1,4-dichlorobenzene, chlorobenzene), PCBs and chlordane (NJDEP, 1986). The method detection limits or "MDLs" (i.e., the lowest concentration level to which a contaminant can be measured by an analytical method with confidence that the level is greater than zero) were less than 1 part per billion (ppb) for all "A-280" contaminants except vinyl chloride (about 1.1 ppb).

Although initial A-280 sampling occurred for some systems in late 1984, most systems began sampling in early 1985. The reporting rate for the initial sampling for the entire state was 90% (NJDEP, 1986). (The reporting rate is not specified for each county.). For the years 1985 through 1988, the reporting rate for the state was between 85% and 90% (NJDEP, 1990). Samples representing the distribution system for each water company serving the 75 towns in the study for the period 1985-88 were used to characterize total VOC (TVOC) and individual VOC levels in each town's system on a monthly basis. The number of distribution samples varied considerably by water company. At a minimum, two samples annually (one in each half of the year) were required. However, if NJ Maximum Contaminant Levels (MCLs) were exceeded for an "A-280" contaminant, additional sampling might be required. In these situations a company might have to sample more than twice a year and/or provide a number of samples (e.g., of each of its wells) per sampling date.

In 1985, 59% (29) of the water companies performed the minimum number of samples required, and 25% (12) performed sampling on five or more occasions during that year. In 1986, 43% (21) performed the minimum number of samples required. Twenty five percent (12) performed sampling on five or more occasions during that year. In 1987, 80% (39) performed the minimum number of samples required and only four companies sampled on five or more occasions during that year. In 1988, 88% (43) performed the minimum number of samples required and only four companies sampled on five or more occasions during that year. Unfortunately, the availability of additional samples did not lead necessarily to a more precise estimation of contamination levels in a water company's system (see the discussion in the Appendix).

The water companies with the minimum number of distribution (tap water) samples per year were almost always the ones with no detected "A-280" contaminants in their samples. For a company with no detected "A-280" contaminants, the estimation process was easy and very precise: it was assumed that all the sources (i.e., wells and/or surface water sources) used by the company were free of "A-280" contaminants (since there was no evidence to the contrary) and the system was given a value of zero for all "A-280" contaminants. For those few water companies which had distribution samples with detectable amounts of "A-280" contaminants but nevertheless sampled only twice yearly, it was often the case that contaminant levels varied only slightly ($\leq$ 1 ppb) between samples so that estimation was again easy and precise.

However, it was almost always difficult to estimate contaminant levels for the water companies that were required to sample frequently. A typical scenario with actual data from the A-280 Program is presented in the Appendix. Typically, the major problems were:

1) A company utilized several wells or wellfields, some of which were contaminated at various levels and some of which were free of contamination, and/or

2) A company purchased large amounts of water from another supplier (usually surface water that was free of "A-280" contaminants), in order to supplement the water in its distribution system coming from its polluted groundwater wells.

Besides additional distribution (tap water) samples, a water company exceeding the NJ MCL for an "A-280" contaminant might be required to sample individual wells or wellfields that constitute all or part of its water supply. A sample of a particular well or wellfield (called a "plant-delivered" sample) is taken at the point where the well's (or wellfield's) water enters the distribution system. A "plant-delivered" sample is indicative not only of contamination levels in the well (or wellfield) water as it enters the distribution system but also of the contamination levels in the distribution system serving homes in the vicinity of the well (i.e., it reflects contamination levels in the tap water of these homes). Homes further away from the well receive a declining amount of water from that well: i.e., their tap water is more of a mixture of water from that well and other wells (or surface water if the company utilizes purchased water from another company).

Although the A-280 Program required a water company to perform samples in locations that are "representative" of the company's distribution system, the company decided where in the distribution system it would sample. A different location might be sampled on each occasion. The result was usually samples that varied widely in amount of contamination detected (see the Appendix).

Usually, a simple average (or weighted average) of the distribution samples was appropriate to estimate levels in a company's distribution system. For example, if

1) a company performed two distribution samples, one in a location near a heavily contaminated well and the other near a relatively "clean" well (or in an area served primarily by purchased surface water), and

2) the company utilized relatively equal amounts of water from the contaminated and "clean" supplies, and

3) most of the population received an equal mixture of the two supplies,

then it would be appropriate to calculate a mean of the samples and use this mean as an estimate of levels in the entire system.

Some of the water companies with complex systems provided us with information on the amount of water used from each of its sources (e.g., individual well daily production logs and the amount of surface water supply purchased from another company) so that weighted averages could be calculated (i.e., weighting the level of contamination in each well or source by the proportion of the total supply it contributes). If a water company with a complex system did not provide information on the amount utilized from each source, then additional assumptions were necessary in the estimation process.

Extensive consultations with BSDW staff occurred during the entire exposure assessment process and BSDW staff reviewed the initial monthly estimates. After this review, each water company was asked to comment on the exposure estimates for its system. After incorporating such information, further revisions to the estimates were made in consultation with BSDW staff. All the estimates were then reviewed once more by BSDW.

In order to estimate monthly exposures to "A-280" contaminants, extrapolation from each sampling date was necessary. Since the A-280 Program often prompted remedial action on the part of the company and/or NJDEP, it was expected that each sample date best reflected recent past and present conditions. After consulting with BSDW, the following algorithm was developed for extrapolating between sampling dates:

> The concentration estimate for a month in which A-280 sampling occurred (a "test-month") was extrapolated backward in time to cover the previous three months and forward in time to cover the following month. If the backward extrapolation overlapped with the forward extrapolation of an earlier "test-month", the backward extrapolation was shortened to cover only the two months previous. If there still was overlapping, then the concentrations for the two test-months were averaged to estimate levels for the overlapped month. If test-months were more than four months apart, then a month was added to both ends of the timeframe covered by each test-month until all months were covered. If an overlap occurred for one month, then the concentrations for the two test-months were averaged.

For the companies performing the minimum number of samples per year, the contamination level estimates for a "test-month" (i.e., a month in which a sample was taken) were simply the levels found in the sample taken during that month. If no contamination was detected, the "test-month" and the months in its coverage period were given a value of zero. This was the approach used for the majority of companies in the study area since most performed only the minimum number of samples. For more complex systems that performed more than one sample in a given month (i.e., those companies utilizing numerous wells and/or which purchased large amounts of water from another company), methods described above for weighting samples taken during a "test-month" were used.

To estimate monthly levels for some of the highly complex systems, it was sometimes necessary to pool samples (distribution and/or "plant-delivered") taken over several adjacent months and calculate a weighted average of these samples. This weighted average would then be assigned to each of these adjacent months. (An example of how monthly levels were determined for one of these highly complex systems is presented in the Appendix). Since the A-280

Program did not begin until late 1984, it was necessary to assign the first "test-month" estimate to all the months in 1984. This assumption was considered reasonable by BSDW. In this way, first trimester exposures could be estimated for those born in early 1985.

If an "A-280" contaminant was not detected in a particular sample, the contaminant was assigned a value of zero for that sample. Following the advice of BSDW, detected levels of methylene chloride were not included in the estimation process. It was the experience of BSDW and NJDEP's Office of Quality Assurance (which certifies labs for the A-280 Program) that detected levels of methylene chloride in drinking water samples were virtually always due to lab contamination (NJDEP, 1987; NJDEP, 1990).

The individual VOCs chosen for separate analyses were the most commonly found "A-280" contaminants in the study area's public water systems. Other "A-280" contaminants, such as vinyl chloride and the xylenes, occurred too infrequently to analyze separately, although they were included in the calculation of "total A-280 volatile organics" (TVOC). PCBs, chlordane, the dichlorobenzenes and trichlorobenzene were not detected in any distribution system or "plant-delivered" samples taken in the study area during the study period.

2.42 TOTAL TRIHALOMETHANES

BSDW's database on total trihalomethane (TTHM) levels in the distribution system of each water company serving at least 1,000 people was obtained for the period 1984-1988. (Levels for individual THMs were not available in this database until 1988.) Samples were required on a quarterly basis by BSDW since TTHM levels varied by season (corresponding to seasonal changes in the amount of organic material or "humics" in the water which react with the chlorine treatment to form THMs).

The locations of the TTHM samples were not available. It was assumed that the water companies, as required by NJDEP, performed the sampling at the furthest reaches of their distribution systems in order to obtain the highest readings of TTHM. (The level of TTHM in the drinking water increases with increasing distance from the point of chlorination treatment since the reactions producing TTHM have more time to take place.)

For water companies that served less than 1,000 people, no data on TTHM were available. These companies utilized groundwater as their source of water supply. After consultation with BSDW, it was assumed that TTHM levels for these companies were at or near the detection level of 1 ppb. In general, compared to surface water, groundwater contains relatively small amounts of organic material or "humics" that react with the chlorine treatment to form THMs. Typically, TTHM levels in groundwater samples are at or near the detection limit of 1 ppb and only rarely exceed 5 ppb.

For each water company, the results of a sampling date were assumed to characterize the season in which the samples were taken. For most systems, four samples were taken on a quarterly sampling date. The mean of these four samples was calculated and assigned to the season covered by the sampling date. Large companies that each served several towns in the study area sampled on two or more occasions during a season. For these companies, a two-step approach was taken to estimate seasonal levels of TTHM. First, the mean of the samples taken on each sampling date was calculated. Then an average was taken of these sampling date means.

As with the estimation of "A280" contaminants, in order to estimate TTHM levels for a town served by a company which utilized groundwater sources and also purchased large amounts of surface water from another company, it was necessary to weight the TTHM levels in each source by the proportion they contributed to the total supply. A sample that was reported as "< 1 ppb" (i.e., below the detection limit) was given the value of 1 ppb when calculating the mean. If the seasonal estimate was less than 5 ppb, it was recoded to zero. Companies not included in the database (i.e., those serving less than 1000 people) were also given the value of zero. Since the only companies with seasonal TTHM estimates below 5 ppb were companies relying solely on groundwater sources, it was assumed that these companies had similar levels of TTHM as those companies that were not represented in the database.

2.43 NITRATES

BSDW supplied data on nitrate levels for the water companies in the study area. Other inorganic contaminants were not evaluated since most of the data merely indicated that levels were below the US Maximum Contamination Levels (MCLs) in drinking water without supplying the actual levels detected. (No company serving the study area exceeded the MCLs for the inorganic contaminants during the study period.). Although the MCL for nitrates (10 ppm) was never exceeded in the study area, the actual levels detected were given in the database. The larger water companies sampled on an annual basis. The level detected in each annual sample was used to characterize the nitrate exposure for the year in which the sample occurred.

Unfortunately, for more than 75% of the companies in the study, sample data were recorded less than annually during the study period. Often only two or three samples were recorded over the entire period 1984 through 1988. For those systems that did not sample on an annual basis, the average of all the samples taken during the period 1984 through 1988 was used to characterize nitrate exposure over the entire study period unless it was known that the water company changed its source of water supply at some point during the study period (e.g., switched from using its well supplies to using purchased surface water supplies from another company). In the latter case, the sample level that appeared to reflect the water source in use in a particular year was used to characterize exposures during that year.

2.5 EXPOSURE VARIABLES

The town of residence of the mother at time of birth was assumed to be her town of residence during the pregnancy. Each month of her pregnancy was assigned the town's monthly estimate for TVOC and the particular "A-280" contaminants, TTHM, and nitrates. In addition, an exposure variable was created that represented the type of water source(s) (i.e., groundwater sources only, surface water source only, or a mixture of both sources) utilized by the company serving the town during the first trimester of the pregnancy. This variable was created so that comparisons could be made with studies that might use a similar variable because they lack data on actual TTHM levels.

For each contaminant, average exposure over the entire pregnancy and average exposure over the first trimester were calculated using the monthly values. Categorical variables were then created from these values. The levels of the categorical variables for TCE and PCE were based on their respective NJ and US MCLs. The categorical variables for DCE, CTC and EDC were based on their NJ MCLs since their US MCLs were rarely if ever exceeded.

The NJ MCLs for benzene and TCA were never exceeded, and no MCL existed for TVOC, so the levels for their categorical variables were chosen based on the distributions for these contaminants. The same approach was taken for nitrates and TTHM, since the nitrate MCL was never exceeded and the TTHM MCL was only rarely exceeded.

Alternate categorical variables were created for all the contaminants except nitrates and benzene. For TVOC, TCE and PCE, the alternative was simply the collapsing of the two highest levels. For DCE, TCA, CTC, EDC and TTHM, the alternative represented another interpretation of the distributions of these contaminants. All categorical variables were created without knowledge of outcome rates.

As stated above, town of residence of the mother at time of birth as recorded on the birth certificate for liveborns, and town of residence at time of death as recorded in the death certificate for fetal deaths, were used to estimate potential exposures to the fetus. This approach assumed:

1) That this residence was also the mother's residence during the pregnancy;

2) That the drinking water supply to this residence was from the public system and not from a private well;

3) That the home did not have an activated charcoal filtering system installed on the entire home's system (i.e., that the water used for

showering, laundry, dishwashing, etc. was all filtered to remove volatile chemicals such as TTHM and the "A-280" contaminants), and

4) That the mother primarily drank and bathed from this supply during the pregnancy (i.e., did not drink and bathe primarily at a workplace or another home located in a town served by a different water company than her residence at time of birth).

A fifth assumption, that the mother used tap water for drinking rather than bottled water or tap water that was filtered at the kitchen faucet, could also be made, although recent studies have indicated that the primary exposure to volatile organics (such as TTHM and the "A-280" contaminants) in drinking water occurs during showering from the inhalation and dermal absorption of the volatilized chemicals (Jo et al., 1990; McKone et al., 1987).

Exposure misclassification due to violations of the above assumptions or due to errors on the birth or fetal death certificates (or data entry errors on the computer tape) concerning mother's town of residence at birth was expected to be non-differential with respect to the outcomes evaluated and therefore was expected to bias results towards the null value.

Additional sources of non-differential exposure misclassification were due to the assumptions made in the estimation of monthly estimates for each town. In particular, it was assumed that all residences in the town were served by public water with the same level of contamination. As stated earlier, the residences closer to the point where a polluted well's supply entered the distribution system would receive water with higher levels of contamination than residences farther away. For TTHM, it is known that tap samples taken at distances farther away from the treatment plant have higher levels of TTHM than samples taken closer to the treatment plant. (NAS, 1982)

In this study, no attempt was made to obtain information from a water company at the level of street block. (In the case-control study which followed this study, the actual residences during pregnancy were obtained through interview, so the effort was made to obtain detailed information from the companies on the sources of water supplied to the street blocks where these residences were located. For example, a company was asked which well(s) supplied the street block of a case or control residence and what percent of the water supplying that block was groundwater. Not all water companies could provide such detailed information.)

2.6 INFORMATION ON OTHER POTENTIAL RISK FACTORS

Information on other potential risk factors was obtained from the vital records tapes for birth certificates and fetal deaths. Descriptive statistics of the demographic information available from birth certificates are given in Table 3.

The potential risk factors included in the regression models for each of the outcomes under study were maternal age, race (white/black/other) and education, primipara (y/n), previous stillbirth (> 20 weeks) or miscarriage (≤ 20 weeks), sex of the birth or fetal death and a variable representing adequacy of prenatal care. Gestational age (based on the date of last menses and date of birth or fetal death) was included in the multiple regression models for birthweight as a continuous variable. The prenatal care variable was created using a standard algorithm (NAS, 1973) and based on information from the birth and fetal death certificate on gestational age, month prenatal care began and number of prenatal visits. Paternal race, age and education were not used in the analyses since the amount of missing data was considerably greater than for the corresponding maternal variables.

During the study period, NJ birth certificates and fetal death certificates did not include information on parental occupation or maternal smoking and alcohol consumption. Although information on complications of pregnancy was collected on the birth certificate, the information was not computerized. APGAR scores were not used in this study.

Bivariate correlations between the above potential risk factors and the only continuous outcome variable in the study (i.e., birthweight among "term" births [259-293 days]) are presented in Table 5. None of the correlations were very strong, but all were higher than the correlations for the (continuous) drinking water exposure variables. The strongest correlation was for gestational age even though the range of gestational ages included in this analysis was extremely narrow. The bivariate correlations between the potential risk factors and the drinking water exposure variables were generally weak; most correlation coefficients were under 0.10 with a few between 0.10 and 0.20. The highest correlations (0.20) involved maternal education, maternal race and prenatal care.

The potential confounding effects of risk factors such as cigarette smoking, alcohol consumption, occupational exposures, exposures in the home, diseases and other complications during pregnancy, substance abuse, and medications taken during pregnancy could not be taken into account in this study. If any of these risk factors were associated with drinking water exposure, the resulting confounding bias could have lead to overestimation or underestimation of the effects of the drinking water exposure on the reproductive outcomes evaluated in this study.

2.7 DATA ANALYSIS

All analyses were performed on a microcomputer using SPSSPC+ (Norusis 1989) and EGRET (SERC, 1990). Multiple regression was the method used in the analysis of birthweight as a continuous variable. Unconditional logistic regression was the method used in all other analyses. For the analyses of the categorical outcomes, one control group was used. As stated previously, the "control" or reference group consisted of all livebirths with no adverse reproductive outcomes (i.e., they were term births that were not low birthweight or small for gestational age and were not registered in the NJ Birth Defects Registry as having congenital anomalies). For the analysis of the continuous outcome, birthweight among "term" (259 - 293 days) livebirths, congenital anomalies other than chromosomal were included.

In order to test the study hypotheses, categorical variables were employed to characterize exposures to TVOC, individual "A-280" VOCs, TTHM and nitrates. Categorical variables are preferred when using exponential methods such as logistic regression, since no assumption is implied about the shape of the response curve (Rothman, 1986; Checkoway et al., 1989). On the other hand, the use of continuous variables in exponential models assumes that the response curve is exponential: i.e., that each additional unit of exposure multiplies the log of the risk or odds of disease by a constant amount. This assumption is often unwarranted and may result in the overestimation of the effects of a risk factor at higher doses or levels.

In non-exponential models such as multiple regression, the use of continuous exposure variables assumes a linear response curve. This assumption is more likely to be the case (Rothman, 1986) and therefore continuous exposure variables were used in the analysis of birthweight for term births. Nevertheless, categorical variables were also employed in this analysis so that other response curve shapes could be evaluated.

In order to decide whether to evaluate the null hypotheses using the adjusted or unadjusted results, the previously mentioned "15% rule" was used. This rule stipulated that unadjusted results could be used if the adjusted results did not differ by more than 15% (Mickey and Greenland, 1989). However, the unadjusted and adjusted results were not strictly comparable since those study subjects with missing values for any of the potential confounders included in the models were excluded from the adjusted analyses. This was not a problem for the analysis of birthweight, since there was virtually no effect on the unadjusted regression coefficients after those with missing values on the potential confounders were excluded. In contrast, for some of the categorical outcomes (e.g., very low birthweight, fetal deaths and the congenital anomalies), the unadjusted odds ratios obtained prior to excluding those with missing values were often profoundly different from the unadjusted odds ratios obtained after the exclusions were made. In order to take into account the impact of these exclusions, the unadjusted odds ratios obtained after making these exclusions (called the "crude odds ratio" in the tables presenting the adjusted results for the categorical outcomes) were compared to the adjusted odds ratios to determine if the 15% rule was met.

In all analyses, statistical significance was determined by the 95% confidence interval. Associations with a one-tailed p-value below 0.05 and a 95% confidence interval which includes 1.0 were reported as "less precise".

Effect modification by the potential risk factors were examined for the odds ratios and multiple regression coefficients of the drinking water exposure variables in addition to effect modification of the odds ratios of the "A-280" contaminants and nitrates due to the inclusion of TTHM in the models. In the few instances where effect modification was evident, it was almost always due to the inclusion of TTHM. However, due to small numbers in each cross-classified stratum, the effect modifications were difficult to interpret and in no instance did it contradict or shed light upon the unadjusted and adjusted results.

3.0 RESULTS

3.1 BIRTHWEIGHT AMONG "TERM" LIVEBIRTHS

Bivariate regressions (i.e. not adjusted) of the birthweight of term births (259-293 days) on the average exposure over the entire pregnancy to each drinking water contaminant (categorical and continuous variables) are presented in Table 6. The R^2 for each regression was very low (< 0.005), which was not surprising given the weak correlations between the drinking water exposure variables and birthweight shown in Table 5. Virtually all findings were statistically significant due to the large numbers of births evaluated. Only TTHM, surface water source and mixed water source were associated with decreasing birthweight.

The adjusted analysis for birthweight is presented in Table 7. Included in the model were variables controlling for maternal age, race and education, prenatal care, parity, previous stillbirth or miscarriage, sex and gestational age of the child, and whether the child was registered as having a congenital anomaly by the NJ Birth Defects Registry. Livebirths with missing data on any of these variables were excluded, but these exclusions did not affect the unadjusted drinking water exposure coefficients. Applying the "15% rule" (i.e., that unadjusted results could be used if the adjusted results did not differ by more than 15%) it was clear from Table 7 that adjustment was necessary since all exposure variable coefficients were sharply reduced after the adjustment. Therefore, the adjusted results were used to evaluate the null hypotheses of no association between the drinking water variables and decreasing birthweight among term births.

After the initial adjustment, the effects of TTHM and surface water source were diminished for TTHM concentrations below 100 ppb but remained associated with decreasing birthweight. At levels of TTHM exposure greater than 100 ppb, the maximum concentration level (standard), the effects of TTHM were unchanged after adjustment and the deficit was 70 grams. After adjustment, most of the "A-280" contaminants no longer had a statistically significant association with increasing birthweight, but TCA, benzene and nitrates continued to be associated with increasing birthweight. In subsequent analyses, these anomalous observations were found to be due to the confounding effects of TTHM; when TTHM was included in the model, the associations with increasing birthweight disappeared.

Among the variables used for adjustment, the following were associated with decreasing birthweight: sex of the child (females were on average 136 grams less than males), race (compared to whites, blacks were about 130 grams less), primipara (100 gram deficit), having a congenital anomaly (140 gram deficit), maternal education less than 12 years (62 gram deficit compared to those with 12-15 years of school) and inadequate prenatal care (55 gram deficit). Even though a narrow range of gestational ages were included in the analysis, gestational age remained a strong predictor of birthweight - a one week increase in gestational age increased birthweight by an average of about 100 grams. Maternal ages of less than 22 years were associated with decreasing birthweight (about 30 grams) while ages over 34 were associated with increasing birthweight (about 30 grams) when compared to ages 22 through 34. Mothers who finished college had higher birthweight babies (33 grams) when compared to those with 12 to 15 years of education. Having a previous stillbirth or miscarriage was not associated with birthweight.

In summary, exposures to TTHM and to a surface water source were associated with decreasing birthweight.

3.2 TERM LOW BIRTHWEIGHT

The unadjusted analysis of term ($\geq$ 37 weeks) low birthweight (< 2500 grams) among livebirths is presented in Table 8. Although chromosomal anomalies were excluded from the "case" group, other congenital anomalies were included in the case group. The exposure of interest was the average exposure over the entire pregnancy to the drinking water contaminants. Almost all of the "A-280" contaminants and nitrates were associated with decreased prevalence of term low birthweight. TTHM and surface water source were associated with a relatively low increase in the prevalence of term low birthweight (odds ratios of about 1.35), and carbon tetrachloride was associated with a higher increase in the prevalence (OR = 1.74).

Table 9 presents the adjusted analysis of term low birthweight. Included in the models were: maternal race, education and age, prenatal care, parity, previous stillbirth or miscarriage and sex of the child. "Cases" (N=67) and "controls" (N=1,113) with missing values for any of these variables were removed from the analysis. In order to apply the "15% rule", it was necessary to take into account the exclusions due to missing values. The column in Table 9 labeled "crude odds ratio" gives the unadjusted odds ratios for the exposure variables after excluding the cases and controls with missing values. These "crude" odds ratios were compared with the adjusted odds ratios using the "15% rule".

The adjusted results for the "A-280" contaminants and nitrates differed from the "crude" results by more than 15%, so the adjusted results in Table 9 were used to evaluate the null hypotheses for these exposures. On the other hand, the adjusted results for TTHM and water source differed from the "crude" results by less than 15%, so the unadjusted results in Table 8 were used to evaluate the null hypotheses for these exposures. After adjustment, the apparent association of the "A-280" contaminants and nitrates with decreased prevalence of term low birthweight disappeared. The statistically significant association for one of the TCA variables (> 1 ppb as the "exposed" group) was ignored since it was inconsistent with the result found for the variable that more precisely defined the exposed group (i.e., > 2 ppb).

Carbon tetrachloride remained associated with an increased prevalence of term low birthweight (OR=2.26).

The relationship between TTHM and term low birthweight was complicated by the lack of linearity of effect (i.e., the odds ratio rose sharply for the 40-60 ppb group and then fell for the 60-80 ppb group). (An exploration of interactions between TTHM and other variables, including other drinking water exposure variables, did not shed any light on this lack of linearity.) Exposure to a mixture of water sources was associated with elevated prevalence (OR=1.17) but the result was not statistically significant.

In summary, exposures to carbon tetrachloride, TTHM, and a surface water source were associated with an increased prevalence of term low birthweight.

3.3 SMALL FOR GESTATIONAL AGE (SGA)

The unadjusted results for SGA are presented in Table 10. As stated previously, chromosomal anomalies were excluded from the case group, but other congenital anomalies were included if they were SGA. The exposure of interest was the average exposure over the entire pregnancy to the drinking water contaminants. Surface water source and the highest level for TTHM were associated with an increased prevalence of SGA (OR=1.22). As with term low birthweight, the effect of TTHM was not linear. On the other hand, the second set of TTHM variables seemed to indicate that the prevalence for SGA increased for those with average exposure over the entire pregnancy greater than 15 ppb, but that the risk reached a plateau at this point.

In the initial analyses, TVOC, PCE, TCA, and nitrates were associated with a decreased prevalence of SGA. When adjustment for TTHM was made, these anomalous associations disappeared. The association between > 1 ppb DCE and decreased prevalence of SGA was ignored since it was inconsistent with the result found for the variable that more precisely defined the exposed group (i.e., > 2 ppb). As with term low birthweight, carbon tetrachloride was associated with increased prevalence of SGA (OR=1.35). However, the odds ratio was considerably less than it was for term low birthweight.

The adjusted results for SGA are presented in Table 11. Two hundred and seventy seven cases and 1,113 controls had missing values for one or more of the variables included in the model and so were excluded from the adjusted analysis. Unlike the analysis of term low birthweight, the adjusted results did not differ by more than 15% from the "crude" results. Therefore the unadjusted results in Table 10 and the results of the adjustment of "A-280" contaminants by TTHM, as described above, were used to evaluate the null hypotheses.

In summary, exposures to carbon tetrachloride, TTHM, and a surface water source were associated with an increased prevalence of SGA.

3.4 PREMATURITY

The unadjusted results for prematurity (i.e., less than 37 weeks gestational age) are presented in Table 12. As stated previously, chromosomal anomalies were excluded from the case group, but other congenital anomalies were included if they were premature. The exposure of interest was the average exposure over the entire pregnancy to the drinking water contaminants.

As with SGA and term low birthweight, the "A-280" contaminants and nitrates were associated with a decreased prevalence of prematurity. TTHM and surface or mixed water source only slightly increased the prevalence of prematurity with odds ratios about 1.10. At the highest levels of TTHM, the association with prematurity was not statistically significant and the effects of TTHM were not linear. The association with mixed source was also not statistically significant.

The adjusted analyses are presented in Table 13. Two hundred and ninety one cases and 1,113 controls had missing values for one or more of the variables included in the model and so were excluded from the adjusted analysis. The adjusted odds ratios differed by more than 15% from the "crude" odds ratios for the "A-280" contaminants and nitrates, so the adjusted results were used to evaluate the null hypotheses. In contrast, for TTHM and water source, the adjusted odds ratios differed little from the "crude" odds ratios, so the unadjusted results were used.

After adjustment, only nitrates had a statistically significant association with a decreased prevalence of prematurity. TVOC, TCA and 1,2-dichloroethane were also associated with decreased prevalence, but their odds ratios were not statistically significant (i.e., 95% confidence interval included 1.0).

In summary, exposure to nitrates was associated with a decreased prevalence of prematurity. Surface water source was associated with an increased prevalence of prematurity.

3.5 VERY LOW BIRTHWEIGHT

The unadjusted results for very low birthweight (< 1500 grams) among livebirths are presented in Table 14. As stated previously, chromosomal anomalies were excluded from the case group, but other congenital anomalies were included if they were premature. The exposure of interest was the average exposure over the entire pregnancy to the drinking water contaminants. As with prematurity, most of the "A-280" contaminants and nitrates were associated with a decreased prevalence of very low birthweight. There was no discernible pattern for TTHM. Only exposure to a surface water source was associated with an increased prevalence of very low birthweight (OR = 1.17).

The adjusted analyses are presented in Table 15. One hundred and thirty cases and 1,113 controls had missing values for one or more of the variables included in the model and were excluded from the adjusted analysis. Similar to the analysis of prematurity, the adjusted odds ratios differed by more than 15% from the "crude" odds ratios for the "A-280" contaminants and nitrates, but not for TTHM and water source. Therefore, the evaluation of the null hypotheses focused on the adjusted results for the "A-280" contaminants and nitrates and the unadjusted results for TTHM and water source. After adjustment, only benzene and nitrates were significantly associated with a decreased prevalence of very low birthweight.

In summary, exposures to benzene and nitrates were associated with a decreased prevalence of very low birthweight. Exposure to a surface water source was associated with an increased prevalence of very low birthweight.

3.6 STILLBIRTHS

The unadjusted results for stillbirths are presented in Table 16. As stated previously, chromosomal anomalies were excluded from the case group, but other stillbirths with congenital anomalies were included. The exposure of interest was the average exposure over the first trimester of the pregnancy to the drinking water contaminants. TCA, 1,2-dichloroethane, and nitrates were consistently associated with a decreased prevalence of stillbirths. Only exposure to a surface water source was associated with an increased prevalence of stillbirths (OR = 1.37). After adjusting for TTHM, the anomalous finding of decreased stillbirth prevalence for EDC disappeared.

The adjusted analyses are presented in Table 17. Only a subset of the variables used in the adjusted analyses of the other outcomes was included in these models: maternal race, age and education, previous stillbirth or miscarriage and prenatal care. Including all the variables used in previous analyses would have meant the exclusion of over 45% (N=274) of the stillbirths. In particular, 187 stillbirths had missing values for parity and 14 stillbirths were missing data on sex. Neither of these variables were strong risk factors in the data; the odds ratios for primipara and sex of the child were 1.33 and 1.03 respectively. Although 177 stillbirths were missing data on prenatal care, this variable was a relatively strong risk factor (OR=2.04) and so was included in the models. The cases had no missing data for the other variables included in the models. The number of controls were excluded because of missing data on the risk factors was 854.

The adjusted results for TTHM, water source, and benzene did not differ by more than 15% from the crude results. In the adjusted analysis of benzene, a less precise association was due to the exclusion of study subjects who had missing values for one or more of the risk factors included in the adjustment. The adjusted results for the rest of the "A-280" contaminants (TVOC, TCE, PCE, DCE, TCA, and CTC) and nitrates differed by more than 15% from the "crude" results. The adjusted results for TCA showed no association with the prevalence of stillbirths. After adjusting for the confounding effects of surface water exposure, the anomalous findings of decreased stillbirth prevalence for nitrates and EDC disappeared. In summary, exposure to a surface water source was associated with an increased prevalence of stillbirths (OR=1.37).

3.7 ALL SURVEILLANCE ANOMALIES

The unadjusted results for all surveillance anomalies are presented in Table 18. The case group included all livebirths that were registered as having a birth defect by the NJ BDR. Stillbirths with birth defects (mostly anencephalus) were ascertained from the cause of death portion of the fetal death certificate and were included in the case group. As stated previously, chromosomal anomalies were excluded. The exposures of interest for the combined and individual birth defects were the average exposures to the drinking water contaminants during the first trimester of the pregnancy.

TTHM and surface water source were associated with an increased prevalence of birth defects. The odds ratio at the highest level of TTHM (> 80 ppb) was 1.58 and the odds ratio for surface water source was 1.31. TVOC and TCA were associated with a decreased prevalence of all surveillance defects combined, but this association disappeared when the analyses adjusted for the confounding effects of TTHM.

The adjusted results for all birth defects combined are presented in Table 19. No adjusted result differed from a "crude" result by more than 15%, so the unadjusted results (and the results for TVOC and TCE after adjustment by TTHM) were used to evaluate the null hypotheses.

3.71 CENTRAL NERVOUS SYSTEM (CNS) DEFECTS

The unadjusted results for CNS defects are presented in Table 20. Carbon tetrachloride (OR = 3.80) and TTHM were associated with an increased prevalence of CNS defects. The odds ratio for the highest level of TTHM (> 80 ppb) was 2.60.

After adjustment for potential confounders, the results for DCE, nitrates, and surface water source differed by more than 15% from the "crude" results. The adjustment attenuated further the association between surface water and CNS defects. However, the adjustment increased the odds ratios for DCE and nitrates.

As seen in Table 21, the adjusted odds ratio for DCE was 2.52 (95% confidence interval = 1.09, 5.8; $p < .035$; "crude" OR = 2.13). Interpreting this result was complicated by the fact that the exclusions of cases and controls due to missing values for the variables in the model increased the unadjusted odds ratio from 1.81 to 2.13. The exclusions of cases and controls were due to missing data for two variables: prenatal care and maternal education. For example, ten cases had missing values for prenatal care and an additional six cases had missing values for maternal education (less than 12 years of education versus 12 or more years) respectively. Both prenatal care and maternal education were relatively strong risk factors with odds ratios of 2.5 and 2.05. Although the adjusted association between nitrates and CNS defects was not statistically significant, there was evidence that the adjusted association was further confounded by TTHM (see Section 2.74).

Tables 22 and 23 present the respective unadjusted results for CNS defects with a single defect diagnosis and CNS defects with multiple defect diagnoses. These analyses are not evaluated for statistical significance, but rather, are presented in order to indicate whether associations found for the combined group holds for both or only one of its subgroups. (An exception was made when a statistically significant association was found for a subgroup and not for the combined group.)

The association with TTHM was primarily among single defect CNS cases, although elevations were also seen for multiple CNS cases. Carbon tetrachloride was associated with elevations in both groups. The association with DCE was seen primarily among single defect cases while that of nitrates was primarily among multiple defect cases. The prevalence of multiple defect cases was elevated at the highest exposure level for TCE (OR = 3.24), but TCE exposure had no association with the prevalence of single defect cases.

In summary, exposures to carbon tetrachloride, dichloroethylenes and TTHM were associated with an increased prevalence of CNS defects. TTHM and carbon tetrachloride increased the prevalence among both single and multiple defect cases. The association with DCE was seen primarily among single defect cases. TCE had a "less precise" association with increased prevalence among multiple defect cases. After adjusting for the confounding effects of TTHM, a less precise association was also found with nitrates (> 2 ppm, OR = 1.77).

For the analyses of the other specific birth defect groups, only the unadjusted results are presented because the adjusted results did not differ by more than 15% from the unadjusted results.

3.71.1 NEURAL TUBE DEFECTS (NTD)

The unadjusted results for NTD are presented in Table 24. Carbon tetrachloride (OR = 5.39) and TTHM were associated with an increased prevalence of NTD. The highest level for TTHM (> 80 ppb) had an odds ratio of 2.98. Suggestive associations were found for TCE above 10 ppb (OR = 2.53), DCE (OR = 2.60), nitrates (OR = 1.82) and mixed water source (OR = 2.34).

Tables 25 and 26 present the unadjusted results for NTDs with a single defect diagnosis and multiple defect diagnoses respectively. The effect of carbon tetrachloride was entirely upon single defect cases. The effect of TTHM was seen primarily among the single defect group, but an elevated prevalence was also found in the multiple defect group. Elevations were seen in both groups for TCE exposure and exposure to a mixed water source. The effect of DCE was seen only among single defect cases, while the effect of nitrates was primarily among multiple defect cases. A strong effect of TVOC was seen among multiple defect cases only; the odds ratio for TVOC levels above 1 ppb was 5.13 (95% confidence interval using the Cornfield method: 1.2, 25.0; exact $p < 0.015$; Note: exact confidence intervals could not be calculated in this study due to the large number of controls.) This effect of TVOC was not evident when single and multiple cases were combined in Table 24.

3.72 ORAL CLEFT DEFECTS

The unadjusted results for oral cleft defects are presented in Table 27. **Exposures to TCE (OR = 2.24, at exposure level "> 5 ppb") and PCE (OR = 3.54, at exposure level " > 10 ppb") were associated with increased prevalence of oral cleft defects. A less precise association was found between carbon tetrachloride and oral clefts (OR = 3.60).** The unadjusted results for cleft lip with or without cleft palate (CLP) and cleft palate without cleft lip (CP) are presented in Tables 28 and 29. The effect of TCE was most evident among CP cases (OR = 3.04 at "> 5 ppb") and the effect of PCE was primarily among CLP cases (OR = 4.33 at "> 10 ppb"), but elevations were seen in both groups for these exposures. Elevations in both groups were also seen for carbon tetrachloride but none were statistically significant. A less precise association was seen for TVOC among CLP cases only (OR = 1.76 at the exposure level "> 5 ppb"). This effect of TVOC was not evident in the combined oral cleft results (Table 27).

3.73 CARDIAC DEFECTS

3.73.1 MAJOR CARDIAC DEFECTS

The unadjusted results for the major cardiac defects are presented in Table 30. The diagnoses included in this category were listed in Table 2. This category included conotruncal defects and flow lesion defects (Boughman et al., 1987). Ventricular septal defects were included in this category only if another heart defect was also present. Exposure to detected amounts of 1,2-dichloroethane was associated with an increased prevalence of major cardiac defects (OR = 2.81). An elevation was also seen at levels above 1 ppb (OR = 2.11) but was not statistically significant. Suggestive associations were found for TTHM (OR = 1.84 for the "> 80 ppb" exposure level) and surface water source (OR = 1.54). A less precise association between TCA and a decreased prevalence of major cardiac defects was also found.

3.73.2 OTHER GROUPINGS OF CONGENITAL HEART DEFECTS

The unadjusted results for ventricular septal defects (VSD) and all cardiac defects are presented in Tables 31 and 32. The VSD group excluded those who had heart defects in addition to VSD. (As indicated above, VSDs were evaluated with other heart anomalies in the "major cardiac defect" group.) No associations were found between the drinking water exposure variables and VSD. (In fact, the only variable associated with VSD was maternal age - an odds ratio of 0.58 for mothers over 34 years compared to either mothers aged 22-34 or mothers aged less than 22 years.)

The "all cardiac defects" group included all surveillance heart defect diagnoses including patent ductus arteriosus (see Table 2). Exposure to a surface water source was associated with all cardiac defects (OR = 1.41). A less precise association was found for TTHM (OR = 1.44 at the level "> 80 ppb"). Associations with a decreased prevalence of all cardiac defects were found for TVOC, DCE, TCA and nitrates, and a less precise association with PCE, but all those negative associations disappeared after adjusting for TTHM and surface water source. In general, the associations with all cardiac defects were relatively weak, indicating that this broad category is less useful in the study of cardiac defects.

3.74 POTENTIAL CONFOUNDING BY OTHER EXPOSURE VARIABLES

Additional analyses were also conducted to test the effects of variables for population density and the Toxics Release Inventory (TRI) data on air emissions. These variables had virtually no confounding effect in the adjusted models.

As noted above, TTHM is inversely related to the "A280" and nitrate exposure variables, so TTHM (when it was found to be associated with a birth outcome) confounded associations of "A280" chemicals and nitrates with reproductive outcomes; therefore, the confounding effect by TTHM was explored. In addition to removing initial anomalous associations between some of the contaminants and decreased prevalence of reproductive outcomes, TTHM also increased the strengths of the relationship of nitrates with CNS defects and NTD; for example, the odds ratio for nitrates and NTDs increased from 1.82 (unadjusted) to 2.72 ($p < 0.015$; 95% CI, 1.3, 5.6) after adjustment for the effects of TTHM. (The effects of the birth certificate risk factors on the odds ratio for nitrates and NTDs were negligible.)

4.0 DISCUSSION

4.1 SUMMARY OF FINDINGS

A matrix of the positive associations meriting further investigation are presented in Table 33. Not listed in the matrix are positive associations (e.g., odds ratios of 2.0 or greater) that lacked sufficient precision; i.e., their 95% confidence intervals included the null value and their two-tailed p-values were greater than 0.10. However, some of these associations might also be worth pursuing further.

There is some concordance between the finding of this study and the findings of the Woburn study and the Finland study of maternal organic solvent exposures at home and at the workplace. In the Woburn study, levels of TCE much higher than the levels found in this study were associated with combined defect grouping "CNS/oral cleft/chromosomal", mainly due to associations between TCE and CNS and chromosomal defects. No association was found with oral clefts alone (Lagakos et al., 1986a). However, in the present study, chromosomal defects were not evaluated, and CNS and oral cleft defects were associated with TCE. In the Finland studies, maternal solvent exposure was associated with CNS defects, oral clefts and VSDs (Holmberg et al., 1980, 1982; Tikkanen and Heinonen, 1988). However, in the present study there were no associations with VSDs and, among the solvents, only 1,2-dichloroethane was associated with major cardiacs. On the other hand, TCE, PCE, DCE and carbon tetrachloride were associated with CNS and/or oral clefts.

The present study does not concur with the findings of the Tucson cardiac defect study (Goldberg et al., 1990). In our study, neither TCE nor DCE were associated with cardiac defects. However, the levels reported in the Tucson study for TCE and DCE were much higher than the levels in the present study.

Exposures to TTHM and to a surface water source were associated with SGA, term low birthweight and birthweight among term births. These outcomes are alternative ways to evaluate the real outcome of interest, i.e. intrauterine growth retardation, and they provide some support for, but are considerably weaker than, the findings of the Iowa study (Kramer et al., 1992). The difference between the present study and the Iowa study could be due to more accurate and precise TTHM data in the latter study. In addition, the Iowan population was probably much more homogeneous (in terms of socioeconomic and other factors) than the NJ population which included a mix of urban and suburban areas. It is most likely that the variables available from the birth and fetal death certificates were inadequate to control for the added "noise" (i.e., confounding bias assumed in this case to be towards the null) that was introduced by the socioeconomic and other factors involved in this urban/suburban mixture.

Finally, this study adds weak support to the findings of the South Australia study regarding nitrates and neural tube and oral cleft defects (Dorsch et al., 1984). In the present study, no association was found with oral clefts and the association with NTDs was much weaker than that found in the South Australia study. These differences could be due to the high levels found in the South Australia study.

The present study does not concur with the New Brunswick study of nitrates and NTDs (Arbuckle, 1988) In that study, nitrate levels in public water systems (virtually all below the MCL of 10 ppm) were not associated with NTDs. In the present study, similar nitrate levels had at least a less precise association with NTDs.

Apart from the human studies mentioned above, there is no toxicological evidence indicating the drinking water contaminants evaluated in this study are teratogenic at the levels found in the public systems in the study area. This lack of evidence is due to the lack of research on the effects of these contaminants at low exposure levels. Indeed there is sparse toxicological data on the reproductive effects of these contaminants at any exposure level. There is some evidence that benzene, TCA, TCE, DCE and PCE are associated with birth defects and/or low birthweight in animal studies (Shepard, 1986). However, currently there is little more than speculation about the possible mechanisms involved in the teratogenic effects of these chemicals at the high doses used in animal research. On the other hand, there are few, if any, animal study data on the reproductive effects of carbon tetrachloride, 1,2-dichloroethane, TTHM and nitrates.

4.2 STRENGTHS AND LIMITATIONS OF THE STUDY DESIGN AND THE DATA

The cross-sectional design of this study enabled us to examine the effects of drinking water exposure on birthweight as a continuous variable. In addition, the design allowed us to examine various adverse reproductive outcomes (e.g., small for gestational age, stillbirths and prematurity) with much greater statistical power than was practical using a case-control design. For example, it would have been impossible with our staff resources and funding to interview 500 or more cases of very low birthweight and an equal number of controls. Yet the cross-sectional design made it possible to include over 900 cases of very low birthweight and many more controls. For most of the outcomes evaluated, there was a sufficient sample size to detect weak to moderate associations. Finally, a cross-sectional study was feasible to perform since the data from the birth and fetal death certificates and the birth defect registrations were computerized and able to be linked.

There were also disadvantages to the cross-sectional design. For example, information was not available on various maternal risk factors such as cigarette and alcohol consumption, occupational exposures, illnesses and medications. If any of these risk factors were associated with drinking water exposure, confounding could lead to overestimation or underestimation of effects.

The computerized birth and fetal death records were known to contain data entry errors (especially for date of last menses) and missing data. The data entry error rate for maternal town of residence was not known. Since street address was not available on the computer tape, it was not known whether there was a problem differentiating mailing and actual residential addresses and, if so, how badly it affected the correct designation of maternal town of residence at birth.

Numerous simplifying assumptions were necessary to perform the exposure assessment. These assumptions probably were a source of exposure misclassification bias that was expected to be non-differential, resulting in a bias towards the null value. For example, an assumption had to be made that residence of the mother at the time of birth or fetal death corresponded to residence at the time of conception and pregnancy. It was necessary to assume that the mother primarily consumed tap water and bathed at the town of residence and not at a workplace or residence in another town. The assumption was made that the mother's residence was served by the public water system and not a private well. Finally, it was assumed that mixing of water sources occurred in the distribution system of each water company and that all residents received this mixture (i.e., that no one received water from a particular public well exclusively).

Non-differential exposure misclassification also may have been introduced by the considerable manipulation and interpretation required in order to estimate monthly exposures to the drinking water contaminants.

The issue of multiple comparisons is often raised in studies such as this one where there are several exposures of interest and several outcomes examined. The contention is that when many comparisons are made, some statistically significant associations will be found even when the null hypothesis of no association is true (i.e., "false positives" will occur). Armitage addressed this issue by making a distinction between a focused approach to the data where "scrutiny is restricted to those comparisons which the data was designed to throw light" vs. "data dredging". He claimed that multiple comparisons were not a problem with the former approach (Armitage, 1971). Rothman recommends that no adjustments (e.g., Bonferroni adjustment) be made when many comparisons are performed. Instead he recommends that each finding "be reported as if it alone were the sole focus of a study" and that all comparisons be reported if possible or, if not possible, then the number of comparisons performed should be stated (Rothman, 1986). In this study, only *a priori* hypotheses are evaluated and all comparisons are reported.

In recent articles, Rothman, Greenland and Robins have argued against the use of multiple-comparisons procedures when the goals are to summarize data and the comparisons of the data with null (or other) hypotheses, to interpret patterns in the data in the light of background information and to identify promising leads for further research (Rothman, 1991; Greenland and Robins, 1991). Greenland and Robins have argued persuasively that *one* multiple-comparison adjustment, empirical-Bayes adjustments, may be useful *if* the objective is a decision-analytic one; i.e., to provide a basis for resource allocation. Clearly this was not the objective of the present study. Given the nascent stage of research on the reproductive effects of drinking water contaminants, the use of multiple-comparisons adjustments in this study would be counterproductive and would obstruct one of the public health goals of the study by making it unduly difficult to identify promising leads for further research.

4.3 CONCLUSION

The objective of this study was to use available sample data on drinking water contaminants in public water systems and data from NJDOH vital records and the Birth Defects Registry to investigate potential relationships between exposures to drinking water contamination and adverse reproductive outcomes. Other than isolated studies of major contamination episodes (e.g., Woburn, Santa Clara, Tucson), research on the effects of drinking water contaminants on reproduction was nonexistent. In particular, no studies had investigated the reproductive effects of these contaminants at the relatively low levels commonly found in public drinking water systems.

Therefore, an additional goal of this study is to encourage other states to investigate the reproductive effects of drinking water contamination using sample data on public systems that have (or will) become available. The USEPA regulations of the Safe Drinking Water Act Amendments of 1986 require public water systems to sample for the specific contaminants evaluated in the present study as well as additional contaminants. In addition, data on TTHM and nitrates has been available for a number of years. It is true that the use of these databases to estimate potential exposures requires much interpretative work on the part of researchers. However, the immense and costly burden of having to perform tap water samples is no longer a barrier to epidemiologic research.

The above findings should be interpreted cautiously: 1) exposure misclassification could lead to underestimation of effects, 2) unmeasured confounding could introduce bias leading to underestimation or overestimation of effects of exposure, and 3) associations could be chance occurrences. In themselves, the positive associations found in this study do not provide sufficient evidence to make the claim that these contaminants cause adverse reproductive outcomes at the levels commonly found in public drinking water systems, and the scarcity of other toxicological and epidemiologic research on the reproductive effects of these drinking water contaminants prevents us from making such claims. Further, the findings of this study do not imply that pregnant women or women considering pregnancy should drink only bottled water; exposures to the contaminants in the study while bathing or showering can be at least as high as exposures through drinking water. Nor do the study findings indicate that citizens should install household filtering systems, particularly since such systems tend to be expensive and require regular maintenance.

Nevertheless, from a public health perspective, the above associations should be taken seriously and investigated further. The findings of this study support continued and enhanced vigilance on the part of USEPA and states to enforce the regulations of the federal Safe Drinking Water and the Clean Water Acts and the analogous state laws. The study findings also support the development of new technologies and practices designed to reduce or eliminate the concentrations of these contaminants in drinking water.

TABLES

TABLE 1

SUMMARY OF STUDIES OF DRINKING WATER CONTAMINATION AND ADVERSE REPRODUCTIVE OUTCOMES

STUDY POPULATION	EXPOSURE	POSITIVE FINDINGS
Woburn, MA (Lagakos, 1986a)	TCE (max = 267 ppb) PCE (max = 21 ppb) Dichloroethylenes (max = 28 ppb) in public water supply	Perinatal mortality, mostly stillbirths (OR = 10, at highest exposure level) The eye/ear defect grouping (OR = 14.9, highest exposure level) The CNS/oral cleft/ chromosomal grouping (OR = 2.3, at highest exposure level)
Battle Creek, MI (Freni, 1988)	TCE, PCE and 1,1-Dichloroethylene in private wells	No positive findings
Santa Clara County, CA (Wrensch, 1990; Swan, 1989)	TCA (max = 1.7 ppm) in a public well serving a census tract.	Cardiac defects? (the spatio-temporal pattern of cardiac defects did not fit the modeled distribution of water from the contaminated well).
Tucson Valley AZ (Goldberg, 1990)	TCE (max = 239 ppb) Dichloroethylene (max = 24 ppb) Chromium in a public wellfield serving the southwestern portion of the city of Tucson	Cardiac defects (exposure prevalence among cases was 3 1/2 times exposure prevalence among controls)
Iowa (Kramer, 1992)	THMs in public drinking water	Small for gestational age (OR = 1.8 with $\geq$ 10 ppb chloroform)

TABLE 1 (continued)

STUDY POPULATION	EXPOSURE	POSITIVE FINDINGS
Massachusetts (Zierler, 1988)	Inorganic levels in public water systems	Arsenic and coarctation of aorta (OR = 3.4)
Massachusetts (Aschengrau, 1989)	Inorganic levels, water hardness, source of water supply (surface or groundwater) - public water systems	Spontaneous abortion and potassium (OR = 2.6); silica (OR = 1.9); water hardness (OR = 2.9); surface water source (OR = 2.2)
South Australia (Dorsch, 1984)	Nitrate levels in drinking water, source of water supply (groundwater contaminated with nitrates or surface water)	Birth defects Neural tube defects (OR = 3.5) Oral clefts (OR = 4.0)
New Brunswick, Canada (Arbuckle, 1988)	Nitrate levels in public water systems and private wells (most of the population exposed to levels below 12 ppm; virtually all public supplies had levels below the US MCL of 10 ppm)	CNS defects for "high" (26 ppm) nitrate levels in private wells (OR = 2.3) (No association found for the lower levels of nitrates found in public water systems)

TABLE 2

PREVALENCE OF SELECTED ADVERSE REPRODUCTIVE OUTCOMES IN THE STUDY AREA NEW JERSEY DEPARTMENT OF HEALTH, 1985 - 1988

TOTAL SINGLETON LIVEBIRTHS IN THE STUDY AREA, 1985-1988: 81,055

ADVERSE REPRODUCTIVE OUTCOME:	NUMBER	% ALL LIVEBIRTHS
TERM LOW BIRTHWEIGHT[1]	1,878	2.3%
SMALL FOR GESTATIONAL AGE (SGA)[2]	8,225	10.1%
VERY LOW BIRTHWEIGHT (< 1500 grams)	924	1.1%
PREMATURITY[3]	7,185	8.9%
STILLBIRTHS (or fetal deaths)[4]	599	0.7%
TOTAL CONGENITAL ANOMALIES[5]	1,247	
# BIRTHS WITH CONGENITAL ANOMALIES[5]	791	1.0%

1 Birthweight less than 2500 grams among term (at least 37 weeks gestation, i.e., ≥259 days) singleton livebirths are included. Excluded were births with no information on birthweight or gestational age.

2 SGA is based on race-sex specific tenth percentile weight for all NJ singleton livebirths, 1985 - 1988. Excluded were births with no information on birthweight or gestational age and gestational ages less than 28 weeks. For those births missing data on race or identified as being a race other than white or black, the tenth percentiles for white births were used.

3 Singleton livebirths with less than 37 weeks gestational age are included. Excluded were births with no information on gestational age.

4 Singleton stillbirths were identified from fetal death certificates. Induced abortions were excluded. Although nineteen of the identified stillbirths had gestational ages of 20 weeks or less, it is known that most fetal deaths of 20 weeks or less gestational age are not issued death certificates and therefore cannot be identified.

5 Birth defects among singleton live births and stillbirths identified from registrations of the NJ Birth Defects Registry and the fetal death tapes. (ICD-9 codes 740.0 - 759.9)

TABLE 2 (continued)

ADVERSE REPRODUCTIVE OUTCOME:	NUMBER	% ALL LIVEBIRTHS
CENTRAL NERVOUS SYSTEM DEFECTS[7]	121	0.15%
NEURAL TUBE DEFECTS[8]	57	0.07%
ALL CARDIAC DEFECTS[9]	370	0.46%
MAJOR CARDIAC DEFECTS[10]	112	0.14%
VENTRICULAR SEPTAL DEFECT[11]	117	0.14%
ORAL CLEFT DEFECTS[12]	86	0.11%
CHROMOSOMAL DEFECTS[13]	122	0.15%

6 Number of singleton livebirths and fetal deaths.

7 Anencephalus and similar anomalies, spina bifida, encephalocele, microcephalus and hydrocephalus without spina bifida (ICD-9 codes: 740.0 - 740.2, 741.0 - 741.9, 742.0, 742.1, 742.3). Included are neural tube defects identified from fetal death certificates.

8 Anencephalus and similar anomalies, spina bifida, encephalocele (ICD-9 codes: 740.0 - 740.2, 741.0 - 741.9, 742.0). Included are neural tube defects identified from fetal death certificates.

9 Common truncus, transposition of great vessels, Tetralogy of Fallot, ventricular septal defect, atrial septal defect, endocardial cushion defects, anomalies of the pulmonary valve, tricuspid atresia and stenosis, aortic valve stenosis and insufficiency, hypoplastic left heart, patent ductus arteriosus, coarctation of aorta and anomalies of the pulmonary artery. (ICD-9: 745.0, 745.1, 745.2, 745.4, 745.5, 745.6, 746.0, 746.1, 746.3, 746.4, 746.7, 747.0, 747.1, 747.3).

10 Common truncus, transposition of great vessels, Tetralogy of Fallot, anomalies of the pulmonary valve, tricuspid atresia and stenosis, aortic valve stenosis and insufficiency, hypoplastic left heart, coarctation of aorta and anomalies of the pulmonary artery. (ICD-9: 745.0, 745.1, 745.2; 746.0, 746.1, 746.3, 746.4, 746.7, 747.1, 747.3).

11 Ventricular septal defect only.

12 Cleft palate without cleft lip, cleft lip with or without cleft palate (ICD-9: 749.0, 749.1-749.2).

13 Trisomy 13, Down Syndrome, Trisomy 18 and other chromosomal anomalies (ICD-9: 758.0 - 758.9).

TABLE 3

DEMOGRAPHIC VARIABLES FROM THE BIRTH CERTIFICATE

NEW JERSEY DEPARTMENT OF HEALTH, 1985 - 1988

	NUMBER	% TOTAL BIRTHS
TOTAL BIRTHS IN THE STUDY AREA, 1985-1988:	82,825	
SINGLETON:	81,055	97.9%
TWINS:	1,668	2.0%
TRIPLETS:	68	0.1%
MISSING DATA ON PLURALITY:	34	0.0%

A) CATEGORICAL VARIABLES

	NUMBER	% SINGLETON BIRTHS
RACE/ETHNICITY OF THE MOTHER		
BLACK:	18,133	22.4%
WHITE:	58,922	72.7%
OTHER:	2,254	2.7%
MISSING DATA:	1,746	2.2%
SEX OF THE CHILD		
MALE:	41,670	51.4%
FEMALE:	39,381	48.6%
MISSING DATA:	4	
PRENATAL CARE		
"ADEQUATE"[1]:	56,240	69.4%
NOT ADEQUATE:	21,026	25.9%
MISSING DATA:	3,789	4.7%
PARITY		
PRIMIPAROUS:	36,868	45.5%
MULTIPAROUS:	41,798	51.6%
MISSING DATA:	2,389	2.9%

TABLE 3 (continued)

	NUMBER	% SINGLE-TON BIRTHS
PREVIOUS MISCARRIAGE		
YES:	15,608	19.3%
MISSING DATA:	1,869	2.3%
PREVIOUS STILLBIRTH		
YES:	1,110	1.4%
MISSING DATA:	1,895	2.3%
MATERNAL EDUCATION		
LESS THAN 12 YEARS:	11,409	14.1%
12 TO 15 YEARS:	45,054	55.6%
GREATER THAN 15 YEARS:	22,102	27.3%
MISSING DATA:	2,490	3.1%
MATERNAL AGE		
LESS THAN 19 YEARS OLD:	4,616	5.7%
19 TO 34 YEARS OLD:	67,811	83.7%
35 YEARS AND OLDER:	8,599	10.6%
MISSING DATA:	29	0.0%

B) CONTINUOUS VARIABLES

VARIABLE	MEAN	(s.d.)	MEDIAN	RANGE	MISSING DATA
MATERNAL AGE	27.6	(5.5)	28.0	10 - 52	29
MATERNAL EDUCATION[2] (years)	13.1	(2.4)	12.0	0 - 17	2,490

1 Based on an algorithm developed by the Institute of Medicine, National Academy of Sciences, which utilizes data from the birth certificate on the month prenatal care began, the number of prenatal visits during the pregnancy and the gestational age of the child (NAS, 1973).

2 Truncated at 17 years of education.

TABLE 4

DESCRIPTIVE STATISTICS OF THE EXPOSURE VARIABLES

NEW JERSEY DEPARTMENT OF HEALTH, 1985 - 1988

1. CONTAMINANT LEVELS IN DRINKING WATER AVERAGED OVER THE ENTIRE PREGNANCY

(ppb)[1]

VARIABLE	MEAN (s.d.)	MEDIAN	RANGE[2]	US MCL[3]
TOTAL "A-280" ORGANICS (TVOC)	2.7 (7.4)	0.2	nd - 75.0	NA
TRICHLOROETHYLENE (TCE)	1.0 (4.3)	nd	nd - 55.0	5
TETRACHLOROETHYLENE (PCE)	0.8 (2.1)	nd	nd - 14.3	5
TOTAL DICHLOROETHYLENES (DCE)	0.2 (0.8)	nd	nd - 11.2	7*
1,1,1-TRICHLOROETHANE (TCA)	0.5 (1.2)	nd	nd - 14.7	200
CARBON TETRACHLORIDE (CTC)	0.1 (0.5)	nd	nd - 7.0	5
BENZENE	< 0.1 (0.1)	nd	nd - 2.0	5
1,2-DICHLOROETHANE (EDC)	0.1 (0.5)	nd	nd - 7.6	5
TOTAL TRIHALOMETHANES (TTHM)	38.1 (30.4)	46.2	nd - 143.6	100
NITRATES (ppm)	1.6 (0.7)	1.5	nd - 4.1	10

1 All values are in parts per billion (ppb) except for nitrates which are in parts per million (ppm).

2 None detected (nd): recoded as zero.

3 The US Maximum Contamination Level in drinking water. Levels are in ppb except for nitrates (ppm). NA = not available.

* the MCL for 1,1-dichloroethylene.

TABLE 4 (continued)

2. PERCENT OF MOTHERS WITH AVERAGE EXPOSURE TO CONCENTRATIONS EQUALING OR EXCEEDING NJ MAXIMUM CONTAMINANT LEVELS (MCLS) IN DRINKING WATER OVER THE ENTIRE PREGNANCY AND DURING ANY MONTH OF THE PREGNANCY, AND THE MAXIMUM MONTHLY ESTIMATE DURING THE STUDY PERIOD.

CONTAMINANT	NJ MCL (ppb)	% OVER ENTIRE PREGNANCY	% ANY MONTH	MAXIMUM MONTHLY ESTIMATE (ppb)
TVOC	none	-	-	75
TCE	1	14.3%	20.5%	55
PCE	1	18.9%	27.8%	26
DCE	2	2.9%	7.3%	16
TCA	26	0	0	18
CTC	2	0.4%	0.7%	5
BENZENE	1	2.4%	2.7%	1
EDC	2	1.6%	1.8%	9
TTHM	100	1.0%	13.7%	299
NITRATES	10 ppm	0	0	4 ppm

TABLE 5

CORRELATION MATRIX RELATING BIRTHWEIGHT (grams) FOR TERM BIRTHS (259-293 days) TO AVERAGE EXPOSURES OVER THE ENTIRE PREGNANCY TO DRINKING WATER CONTAMINANTS AND OTHER POTENTIAL RISK FACTORS

NEW JERSEY DEPARTMENT OF HEALTH, 1985 - 1988

VARIABLE	N*	CORRELATION COEFFICIENT
TRICHLOROETHYLENE (TCE)	59,151	0.011
TETRACHLOROETHYLENE (PCE)	59,151	0.016
THE DICHLOROETHYLENES (DCE)	59,151	0.025
1,1,1-TRICHLOROETHANE (TCA)	59,151	0.038
CARBON TETRACHLORIDE (CTC)	59,151	0.004
1,2-DICHLOROETHANE (EDC)	59,151	0.008
BENZENE	59,151	0.018
NITRATES	59,151	0.007
TOTAL TRIHALOMETHANES (TTHM)	59,151	- 0.041
MATERNAL AGE (continuous):	59,147	0.130
< 18 years: (ref = all other ages)		- 0.078
18 - 21 years: " "		- 0.085
22 - 34 years: " "		0.015
> 34 years: " "		0.046
MATERNAL EDUCATION (continuous):	58,792	0.115
< 12 years: (ref = all other years)		- 0.104
12 - 15 years: " "		- 0.013
> 15 years: " "		0.090

TABLE 5 (continued)

VARIABLE	N*	CORRELATION COEFFICIENT
MATERNAL RACE	58,980	
WHITE: (ref = Black and Other)		0.167
BLACK: (ref = White and Other)		- 0.156
OTHER: (ref = White and Black)		- 0.046
PRIMIPARA (0=n, 1=y)	58,714	- 0.088
INADEQUATE PRENATAL VISITS (0=n, 1=y)	58,416	- 0.118
SEX OF THE CHILD (m=1, f=2)	59,151	- 0.135
GESTATIONAL AGE (weeks)	59,151	0.254

* pair-wise deletion for missing values. (Number of births with valid birthweights = 59,151)

TABLE 6

UNADJUSTED ANALYSES OF BIRTHWEIGHT (grams) FOR TERM BIRTHS AND MEAN EXPOSURE OVER THE ENTIRE PREGNANCY TO DRINKING WATER CONTAMINANTS NEW JERSEY DEPARTMENT OF HEALTH, 1985 - 1988

N = 59,151

CONTAMINANT	N	REGRESSION COEFFICIENT	(s.e.)	REFERENCE WEIGHT (g)	2-tail P-VALUE
TVOC (continuous)		1.45	(0.27)		< 0.001
(ref: ≤ 1 ppb)	39,650	-		3403.2	-
> 1 - 5 ppb	11,644	31.0	(5.1)		< 0.001
> 5 - 10 ppb	3,762	22.2	(8.3)		< 0.08
> 10 ppb	4,095	53.5	(8.0)		< 0.001
TCE (continuous)		1.28	(0.46)		< 0.01
(ref: ≥ 1 ppb)	51,607	-		3410.8	-
> 1 - 5 ppb	4,575	23.2	(7.5)		< 0.005
> 5 - 10 ppb	1,397	37.1	(13.2)		< 0.01
> 10 ppb	1,572	35.9	(12.5)		< 0.005
PCE (continuous)		3.84	(0.97)		< 0.001
(ref: ≤ 1 ppb)	48,281	-		3411.3	-
> 1 - 5 ppb	7,548	8.3	(6.1)		NS
> 5 - 10 ppb	2,792	33.2	(9.5)		< 0.001
> 10 ppb	530	47.7	(21.3)		< 0.03
DCE (continuous)		14.1	(2.37)		< 0.001
(ref: ≤ 2 ppb)	57,893	-		3413.5	-
> 2 ppb	1,258	43.2	(13.9)		< 0.005
(ref: ≤ 1 ppb)	55,020	-		3410.1	-
> 1 ppb	4,131	61.3	(7.9)		< 0.001
TCA (continuous)		14.81	(1.62)		< 0.001
(ref: ≤ 2 ppb)	55,635	-		3409.8	-
> 2 ppb	3,516	77.1	(8.5)		< 0.001
(ref: ≤ 1 ppb)	51,307	-		3405.8	-
> 1 ppb	7,844	65.1	(5.9)		< 0.001
CTC (continuous)		4.31	(4.29)		NS
(ref: ≤ 1 ppb)	58,781	-		3414.3	-
> 1 ppb	370	10.4	(25.5)		NS
(ref: not detected)	56,419	-		3412.2	-
detected	2,732	47.8	(9.6)		< 0.001

TABLE 6 (continued)

CONTAMINANT	N	REGRESSION COEFFICIENT (s.e.)		REFERENCE WEIGHT (g)	2-tail P-VALUE
EDC (continuous)		7.32	(4.02)		< 0.07
(ref: ≤ 1 ppb)	58,117	-		3413.9	-
> 1 ppb	1,034	30.5	(15.3)		< 0.05
(ref: not detected)	57,774	-		3413.5	-
detected	1,377	39.4	(13.3)		< 0.005
BENZENE (continuous)		101.8	(23.94)		< 0.001
(ref: not detected)	57,434	-		3413.3	-
detected	1,717	37.7	(12.0)		< 0.005
NITRATES (continuous)		4.73	(2.71)		< 0.085
(ref: ≤ 2 ppb)	50,817	-		3402.5	-
>2 ppb	8,334	84.3	(5.8)		< 0.001
TTHM (continuous)		-0.65	(0.07)		< 0.001
(ref: ≤ 20 ppb)	22,098	-		3437.5	-
> 20 - 40 ppb	3,300	34.8	(9.1)		< 0.005
> 40 - 60 ppb	17,904	-51.2	(4.9)		< 0.001
> 60 - 80 ppb	11,199	-26.6	(5.7)		< 0.001
> 80 ppb	4,650	-57.4	(7.9)		< 0.001
>80 - 100 ppb	3,898	-54.9	(8.5)		< 0.001
>100 ppb	752	-70.4	(18.1)		< 0.001
TTHM*					
(ref: ≤ 15 ppb)	21,310	-		3439.5	-
> 15 - 50 ppb	12,908	-27.3	(5.4)		< 0.001
> 50 - 75 ppb	17,502	-50.8	(5.0)		< 0.001
> 75 ppb	7,431	-32.8	(6.6)		< 0.001
WATER SOURCE:					
(ref: groundwater)	19,125	-		3447.9	-
SURFACE WATER	33,169	-55.3	(4.4)		< 0.001
MIXTURE	6,857	-21.8	(6.9)		< 0.005

NS: two-tail p-value ≥ 0.10

NOTE: The R-squares for the regressions were less than 0.005.

* An alternative categorization of TTHM.

TABLE 7

MULTIPLE REGRESSION ANALYSES OF BIRTHWEIGHT FOR TERM BIRTHS AND

MEAN EXPOSURE OVER THE ENTIRE PREGNANCY TO DRINKING WATER

CONTAMINANTS CONTROLLING FOR SELECTED RISK FACTORS*
NEW JERSEY DEPARTMENT OF HEALTH, 1985 - 1988

N = 57,696

CONTAMINANT	REGRESSION COEFFICIENT (s.e.)		2-tail P-VALUE
TVOC (continuous)	0.24	(0.26)	NS
(ref: ≤ 1 ppb)	-		-
> 1 - 5 ppb	24.6	(4.9)	< 0.001
> 5 - 10 ppb	5.3	(7.9)	NS
> 10 ppb	7.2	(7.7)	NS
TCE (continuous)	0.20	(0.44)	NS
(ref: ≤ 1 ppb)	-		-
> 1 - 5 ppb	3.3	(7.2)	NS
> 5 - 10 ppb	-14.9	(12.5)	NS
> 10 ppb	10.9	(11.9)	NS
PCE (continuous)	0.61	(0.92)	NS
(ref: ≤ 1 ppb)	-		-
> 1 - 5 ppb	10.7	(5.8)	< 0.07
> 5 - 10 ppb	2.4	(9.0)	NS
> 10 ppb	-12.7	(20.4)	NS
DCE (continuous)	1.05	(2.28)	NS
(ref: ≤ 2 ppb)	-		-
> 2 ppb	-12.1	(13.3)	NS
(ref: _ 1 ppb)	-		-
> 1 ppb	11.0	(7.5)	NS
TCA (continuous)	3.24	(1.56)	< 0.04
(ref: ≤ 2 ppb)	-		-
> 2 ppb	16.0	(8.1)	< 0.05
(ref: ≤ 1 ppb)	-		-
> 1 ppb	13.4	(5.7)	< 0.02
CTC (continuous)	-2.04	(4.08)	NS
(ref: ≤ 1 ppb)	-		-
> 1 ppb	-15.2	(24.2)	NS
(ref: not detected)	-		-
detected	-8.0	(9.1)	NS

TABLE 7 (continued)

CONTAMINANT	REGRESSION COEFFICIENT (s.e.)		2-tail P-VALUE
EDC (continuous)	3.02	(3.80)	NS
(ref: ≤ 1 ppb)	-		-
> 1 ppb	12.0	(14.6)	NS
(ref: not detected)	-		-
detected	11.8	(12.6)	NS
BENZENE (continuous)	59.74	(22.98)	< 0.01
(ref: not detected)	-		-
detected	4.9	(11.4)	NS
NITRATES (continuous)	5.27	(2.60)	< 0.045
(ref: ≤ 2 ppb)	-		-
>2 ppb	22.6	(5.6)	< 0.001
TTHM (continuous)	-0.41	(0.06)	< 0.001
(ref: ≤ 20 ppb)	-		-
> 20 - 40 ppb	7.6	(8.7)	NS
> 40 - 60 ppb	-30.4	(4.8)	< 0.001
> 60 - 80 ppb	-20.6	(5.4)	< 0.001
> 80 ppb	-37.2	(7.5)	< 0.001
> 80 - 100 ppb	-30.7	(8.0)	< 0.001
> 100 ppb	-70.4	(17.0)	< 0.001
TTHM (ref: ≤ 15 ppb)	-		-
> 15 - 50 ppb	-18.5	(5.2)	< 0.001
> 50 - 75 ppb	-29.4	(4.8)	< 0.001
> 75 ppb	-27.0	(6.2)	< 0.001
WATER SOURCE:			
(ref: groundwater)	-		-
SURFACE WATER	-31.3	(4.3)	< 0.001
MIXTURE	-6.7	(6.5)	NS

NS = two-tail p-value ≥ 0.10

NOTE: The R-squares for all the regressions equaled 0.13.

* Included in the model from information available on the birth certificate were sex and gestational age of the child, inadequate prenatal visits (based on when care was sought and the number of visits per gestational age of the child - see text), and the following maternal factors: race (b/w/other), age, education, parity and previous miscarriage or stillbirth. In addition, a variable indicating whether the child was identified as having a congenital malformation by the NJ Birth Defects Registry was included in the model.

TABLE 8

Bivariate Odds Ratios. New Jersey Dept. of Health 1985-1988
OUTCOME: Term Low Birthweight

CASES = 1853 CONTROLS = 52,334

CONTAMINANT LEVELS[1]	# CASES	# CONTROLS	ODDS RATIO	95% CONFIDENCE INTERVAL	2-TAIL P-VALUE[2]
A-280 TOTAL VOLATILE ORGANICS:					
n.d. - 1 ppb (ref)	1303	34,991	1.00	---	---
> 1 ppb - 5 ppb	345	10,382	0.89	0.79 - 1.01	< .065
> 5 ppb - 10 ppb	109	3,334	0.88	0.72 - 1.1	NS
> 10 ppb	96	3,627	0.71	0.58 - 0.88	< .005
> 5 ppb	205	6,961	0.79	0.68 - 0.92	< .005
TRICHLOROETHYLENE:					
n.d. - 1 ppb (ref)	1659	45,635	1.00	---	---
> 1 ppb - 5 ppb	121	4,091	0.81	0.67 - 0.98	< .035
> 5 ppb - 10 ppb	31	1,236	0.69	0.48 - 0.99	< .045
> 10 ppb	42	1,372	0.84	0.62 - 1.2	NS
> 5 ppb	73	2,608	0.77	0.60 - 0.98	< .04
TETRACHLOROETHYLENE:					
n.d. - 1 ppb (ref)	1525	42,657	1.00	---	---
> 1 ppb - 5 ppb	251	6,737	1.04	0.91 - 1.2	NS
> 5 ppb - 10 ppb	66	2,472	0.75	0.58 - 0.96	< .025
> 10 ppb	11	468	0.66	0.36 - 1.2	NS
> 5 ppb	77	2,940	0.73	0.58 - 0.92	< .01
DICHLOROETHYLENES:					
n.d. - 2 ppb (ref)	1818	51,224	1.00	---	---
> 2 ppb	35	1,110	0.89	0.63 - 1.3	NS
n.d. - 1 ppb (ref)	1772	48,647	1.00	---	---
> 1 ppb	81	3,687	0.60	0.48 - 0.76	< .001
1,1,1-TRICHLOROETHANE:					
n.d. - 2 ppb (ref)	1779	49,184	1.00	---	---
> 2 ppb	74	3,150	0.65	0.51 - 0.82	< .001
n.d. - 1 ppb (ref)	1691	45,336	1.00	---	---
> 1 ppb	162	6,998	0.62	0.53 - 0.73	< .001

TABLE 8 (continued)
OUTCOME: Term Low Birthweight

CONTAMINANT LEVELS[1]	# CASES	# CONTROLS	ODDS RATIO	95% CONFIDENCE INTERVAL	2-TAIL P-VALUE[2]
CARBON TETRACHLORIDE:					
n.d. - 1 ppb (ref)	1834	49,910	1.00	---	---
> 1 ppb	19	2,424	1.74	1.10 - 2.8	< .002
not detected (ref)	1786	49,910	1.00	---	---
detected	67	2,424	0.77	0.60 - 0.99	< .045
1,2-DICHLOROETHANE:					
n.d. - 1 ppb (ref)	1832	51,426	1.00	---	---
> 1 ppb	21	908	0.65	0.42 - 1.0	< .055
not detected (ref)	1828	51,117	1.00	---	---
detected	25	1,217	0.57	0.39 - 0.86	< .01
BENZENE:					
not detected (ref)	1816	50,813	1.00	---	---
detected	37	1,217	0.68	0.48 - 0.96	< .03
NITRATES:					
n.d. - 2 ppm (ref)	1683	44,872	1.00	---	---
> 2 ppm	170	7,462	0.61	0.52 - 0.71	< .001
TOTAL TRIHALOMETHANES:					
n.d.- 20 ppb (ref)	618	19,766	1.00	---	
> 20 ppb - 40 ppb	71	2,936	0.77	0.60 - 0.99	< .045
> 40 ppb - 60 ppb	645	15,657	1.32	1.18 - 1.50	< .001
> 60 ppb - 80 ppb	349	9,913	1.13	0.99 - 1.3	< .075
> 80 ppb	170	4,062	1.34	1.13 - 1.6	< .001
n.d.- 15 ppb (ref)	587	19,076	1.00	---	
> 15 ppb - 50 ppb	417	11,367	1.19	1.05 - 1.4	< .01
> 50 ppb - 75 ppb	623	15,344	1.32	1.18 - 1.5	< .001
> 75 ppb	226	6,547	1.12	0.96 - 1.3	NS
SOURCE OF WATER SUPPLY[3]:					
ground water (ref)	500	17,157	1.00	---	
surface water	1146	29,078	1.35	1.22 - 1.5	< .001
mixture of sources	207	6,099	1.17	0.99 - 1.4	< .075

1 estimated average contaminant levels in drinking water during entire pregnancy.

ref = referent group n.d. = not detected
ppb = parts per billion ppm = parts per million

2 NS the two-tail p-value is greater than 0.10.

3 Predominant (> 85%) source of the water supply during the entire pregnancy. ("Mixture of sources" indicates that the water company's supply consisted of at least 15% from each source during the first trimester.)

TABLE 9
Adjusted Odds Ratios New Jersey Dept. of Health 1985-1988
OUTCOME: Term Low Birthweight

CASES = 1786 CONTROLS = 51,221

AVERAGE FIRST TRIMESTER CONTAMINANT LEVELS	ADJUSTED ODDS RATIO	95% CONFIDENCE INTERVAL	2-TAIL P-VALUE	"CRUDE" ODDS RATIO[1]
TOTAL A-280 VOLATILES:				
> 1 ppb - 5 ppb	0.90	0.79 - 1.02	< .09	0.87
> 5 ppb - 10 ppb	0.95	0.78 - 1.2	NS	0.87
> 10 ppb	0.97	0.78 - 1.2	NS	0.71
> 5 ppb	0.96	0.82 - 1.1	NS	0.79
TRICHLOROETHYLENE:				
> 1 ppb - 5 ppb	0.87	0.71 - 1.05	NS	0.80
> 5 ppb - 10 ppb	1.05	0.73 - 1.5	NS	0.71
> 10 ppb	1.05	0.76 - 1.4	NS	0.85
> 5 ppb	1.05	0.82 - 1.3	NS	0.78
TETRACHLOROETHYLENE:				
> 1 ppb - 5 ppb	1.02	0.88 - 1.2	NS	1.04
> 5 ppb - 10 ppb	0.90	0.70 - 1.2	NS	0.75
> 10 ppb	0.93	0.50 - 1.8	NS	0.63
> 5 ppb	0.90	0.71 - 1.2	NS	0.73
The DICHLOROETHYLENES:				
> 2 ppb	1.31	0.93 - 1.9	NS	0.91
> 1 ppb	0.85	0.68 - 1.1	NS	0.61
1,1,1-TRICHLOROETHANE:				
> 2 ppb	0.93	0.73 - 1.2	NS	0.64
> 1 ppb	0.82	0.69 - 0.90	< .03	0.59
CARBON TETRACHLORIDE:				
> 1 ppb	2.26	1.41 - 3.6	< .001	1.84
detected	1.10	0.86 - 1.4	NS	0.78
1,2-DICHLOROETHANE:				
> 1 ppb	0.75	0.48 - 1.2	NS	0.64
detected	0.70	0.46 - 1.05	< .09	0.57

TABLE 9 (continued)
OUTCOME: Term Low Birthweight

AVERAGE FIRST TRIMESTER CONTAMINANT LEVELS	ADJUSTED ODDS RATIO	95% CONFIDENCE INTERVAL	2-TAIL P-VALUE	"CRUDE" ODDS RATIO[1]
BENZENE:				
detected	0.84	0.59 - 1.2	NS	0.67
NITRATES:				
> 2 ppm	0.89	0.75 - 1.05	NS	0.61
TOTAL TRIHALOMETHANES:				
> 20 ppb - 40 ppb	0.92	0.71 - 1.2	NS	0.75
> 40 ppb - 60 ppb	1.23	1.09 - 1.4	< .001	1.34
> 60 ppb - 80 ppb	1.12	0.98 - 1.3	< .10	1.11
> 80 ppb	1.29	1.08 - 1.5	< .01	1.39
> 15 - 50 ppb	1.17	1.03 - 1.3	< .025	1.21
> 50 - 75 ppb	1.23	1.09 - 1.4	< .001	1.33
> 75 ppb	1.16	0.99 - 1.4	< .075	1.16
WATER SOURCE:				
surface water	1.24	1.11 - 1.4	< .001	1.38
mixture of sources	1.10	0.93 - 1.3	NS	1.18

1 The unadjusted odds ratio after removal of cases and controls with missing data on any of the factors included in the model.

ppb = parts per billion
ppm = parts per million
NS = two-tail p-value ≥ 0.10

Factors adjusted for in the model:

race of the mother (white/black/other)
maternal age (< 20, 20-34, ≥ 35)
maternal education (< 12, 12-15, ≥ 16)
parity (primipara/multipara)
previous adverse reproductive outcome (y/n)
"adequacy" of prenatal care (y/n) based on the trimester that care was first obtained and the number of visits per gestational age
sex of child

TABLE 10
Bivariate Odds Ratios. New Jersey Dept. of Health 1985-1988
OUTCOME: Small For Gestational Age

CASES = 8173 CONTROLS = 52,334

CONTAMINANT LEVELS[1]	# CASES	# CONTROLS	ODDS RATIO	95% CONFIDENCE INTERVAL	2-TAIL P-VALUE[2]
A-280 TOTAL VOLATILE ORGANICS:					
n.d. - 1 ppb (ref)	5639	34,991	1.00	---	---
> 1 ppb - 5 ppb	1510	10,382	0.90	0.85 - 0.96	< .001
> 5 ppb - 10 ppb	510	3,334	0.95	0.86 - 1.05	NS
> 10 ppb	514	3,627	0.88	0.80 - 0.97	< .01
> 5 ppb	1024	6,961	0.91	0.85 - 0.98	< .015
TRICHLOROETHYLENE:					
n.d. - 1 ppb (ref)	7190	45,635	1.00	---	---
> 1 ppb - 5 ppb	587	4,091	0.91	0.83 - 1.0	< .045
> 5 ppb - 10 ppb	180	1,236	0.92	0.79 - 1.1	NS
> 10 ppb	216	1,372	1.00	0.86 - 1.2	NS
> 5 ppb	396	2,608	0.96	0.86 - 1.1	NS
TETRACHLOROETHYLENE:					
n.d. - 1 ppb (ref)	6766	42,657	1.00	---	---
> 1 ppb - 5 ppb	988	6,737	0.93	0.86 - 0.99	< .035
> 5 ppb - 10 ppb	351	2,472	0.90	0.80 - 1.01	< .06
> 10 ppb	68	468	0.92	0.70 - 1.2	NS
> 5 ppb	419	2,940	0.90	0.81 - 1.0	< .05
DICHLOROETHYLENES:					
n.d. - 2 ppb (ref)	8005	51,224	1.00	---	---
> 2 ppb	168	1,110	0.97	0.82 - 1.1	NS
n.d. - 1 ppb (ref)	7678	48,647	1.00	---	---
> 1 ppb	495	3,687	0.85	0.77 - 0.94	< .005
1,1,1-TRICHLOROETHANE:					
n.d. - 2 ppb (ref)	7756	49,184	1.00	---	---
> 2 ppb	417	3,150	0.84	0.76 - 0.93	< .005
n.d. - 1 ppb (ref)	7198	45,336	1.00	---	---
> 1 ppb	975	6,998	0.88	0.82 - 0.94	< .001

TABLE 10 (continued)
OUTCOME: Small For Gestational Age

CONTAMINANT LEVELS[1]	# CASES	# CONTROLS	ODDS RATIO	95% CONFIDENCE INTERVAL	2-TAIL P-VALUE[2]
CARBON TETRACHLORIDE:					
n.d. - 1 ppb (ref)	8108	52,025	1.00	---	---
> 1 ppb	65	309	1.35	1.03 - 1.8	< .03
not detected (ref)	7820	49,910	1.00	---	---
detected	353	2,424	0.93	0.83 - 1.04	NS
1,2-DICHLOROETHANE:					
n.d. - 1 ppb (ref)	8037	51,426	1.00	---	---
> 1 ppb	136	908	0.96	0.80 - 1.2	NS
not detected (ref)	8005	51,117	1.00	---	---
detected	168	1,217	0.88	0.75 - 1.04	NS
BENZENE:					
not detected (ref)	7959	50,813	1.00	---	---
detected	214	1,217	0.90	0.78 - 1.04	NS
NITRATES:					
n.d. - 2 ppm (ref)	7177	44,872	1.00	---	---
> 2 ppm	996	7,462	0.83	0.78 - 0.90	< .001
TOTAL TRIHALOMETHANES:					
n.d.- 20 ppb (ref)	2814	19,766	1.00	---	
> 20 ppb - 40 ppb	411	2,936	0.98	0.88 - 1.1	NS
> 40 ppb - 60 ppb	2704	15,657	1.21	1.15 - 1.3	< .001
> 60 ppb - 80 ppb	1539	9,913	1.09	1.02 - 1.2	< .015
> 80 ppb	705	4,062	1.22	1.12 - 1.3	< .001
n.d.- 15 ppb (ref)	2699	19,076	1.00	---	---
> 15 ppb - 50 ppb	1861	11,367	1.16	1.09 - 1.2	< .001
> 50 ppb - 75 ppb	2545	15,344	1.17	1.11 - 1.2	< .001
> 75 ppb	1068	6,547	1.15	1.07 - 1.2	< .001
SOURCE OF WATER SUPPLY[3]:					
ground water (ref)	2378	17,157	1.00	---	
surface water	4913	29,078	1.22	1.16 - 1.3	< .001
mixture of sources	882	6,099	1.04	0.96 - 1.1	NS

1 estimated average contaminant levels in drinking water during entire pregnancy.

ref = referent group n.d. = not detected
ppb = parts per billion ppm = parts per million

2 NS = the two-tail p-value is greater than 0.10.

3 Predominant (> 85%) source of the water supply during the first trimester. ("Mixture of sources" indicates that the water company's supply consisted of at least 15% from each source during the first trimester.)

TABLE 11

Adjusted Odds Ratios New Jersey Dept. of Health 1985-1988

OUTCOME: Small for Gestational Age

CASES = 7896 CONTROLS = 51,221

AVERAGE FIRST TRIMESTER CONTAMINANT LEVELS	ADJUSTED ODDS RATIO	95% CONFIDENCE INTERVAL	2-TAIL P-VALUE	"CRUDE" ODDS RATIO[1]
TOTAL A-280 VOLATILES:				
> 1 ppb - 5 ppb	0.91	0.85 - 0.97	< .005	0.89
> 5 ppb - 10 ppb	0.99	0.90 - 1.1	NS	0.94
> 10 ppb	0.95	0.86 - 1.05	NS	0.88
> 5 ppb	0.97	0.90 - 1.04	NS	0.91
TRICHLOROETHYLENE:				
> 1 ppb - 5 ppb	0.96	0.87 - 1.05	NS	0.91
> 5 ppb - 10 ppb	1.04	0.89 - 1.2	NS	0.92
> 10 ppb	0.97	0.84 - 1.1	NS	1.0
> 5 ppb	1.0	0.90 - 1.1	NS	0.96
TETRACHLOROETHYLENE:				
> 1 ppb - 5 ppb	0.99	0.92 - 1.07	NS	0.93
> 5 ppb - 10 ppb	0.94	0.83 - 1.05	NS	0.89
> 10 ppb	1.06	0.81 - 1.4	NS	0.89
> 5 ppb	0.95	0.86 - 1.06	NS	0.89
The DICHLOROETHYLENES:				
> 2 ppb	1.08	0.91 - 1.3	NS	0.97
> 1 ppb	0.92	0.83 - 1.02	NS	0.84
1,1,1-TRICHLOROETHANE:				
> 2 ppb	0.93	0.84 - 1.04	NS	0.83
> 1 ppb	0.92	0.85 - 0.99	< .03	0.85
CARBON TETRACHLORIDE:				
> 1 ppb	1.34	1.02 - 1.8	< .04	1.4
detected	1.01	0.90 - 1.1	NS	0.93
1,2-DICHLOROETHANE:				
> 1 ppb	0.90	0.75 - 1.1	NS	0.95
detected	0.86	0.73 - 1.02	< .08	0.88

TABLE 11 (continued)
OUTCOME: Small for Gestational Age

AVERAGE FIRST TRIMESTER CONTAMINANT LEVELS	ADJUSTED ODDS RATIO	95% CONFIDENCE INTERVAL	2-TAIL P-VALUE	"CRUDE" ODDS RATIO[1]
BENZENE:				
detected	0.89	0.76 - 1.03	NS	0.89
NITRATES:				
> 2 ppm	0.92	0.86 - 0.99	< .04	0.84
TOTAL TRIHALOMETHANES:				
> 20 ppb - 40 ppb	0.99	0.88 - 1.1	NS	0.99
> 40 ppb - 60 ppb	1.07	1.01 - 1.1	< .035	1.22
> 60 ppb - 80 ppb	1.03	0.96 - 1.1	NS	1.10
> 80 ppb	1.14	1.04 - 1.3	< .005	1.25
> 15 - 50 ppb	1.06	0.99 - 1.1	< .08	1.17
> 50 - 75 ppb	1.06	1.00 - 1.1	< .075	1.19
> 75 ppb	1.11	1.02 - 1.2	< .015	1.18
WATER SOURCE:				
surface water	1.10	1.04 - 1.2	< .001	1.24
mixture of sources	1.03	0.94 - 1.1	NS	1.06

1 The unadjusted odds ratio after removal of cases and controls with missing data on any of the factors included in the model.

ppb = parts per billion
ppm = parts per million
NS = two-tail p-value ≥ 0.10

Factors adjusted for in the model:

race of the mother (white/black/other)
maternal age (< 20, 20-34, ≥ 35)
maternal education (< 12, 12-15, ≥ 16)
parity (primipara/multipara)
previous adverse reproductive outcome (y/n)
"adequacy" of prenatal care (y/n) based on the trimester that care was first obtained and the number of visits per gestational age
sex of child

TABLE 12
Bivariate Odds Ratios. New Jersey Dept. of Health 1985-1988
OUTCOME: Prematurity

CASES = 7167 CONTROLS = 52,334

CONTAMINANT LEVELS[1]	# CASES	# CONTROLS	ODDS RATIO	95% CONFIDENCE INTERVAL	2-TAIL P-VALUE[2]
A-280 TOTAL VOLATILE ORGANICS:					
n.d. - 1 ppb (ref)	5002	34,991	1.00	---	---
> 1 ppb - 5 ppb	1412	10,382	0.95	0.89 - 1.01	NS
> 5 ppb - 10 ppb	379	3,334	0.80	0.71 - 0.89	< .001
> 10 ppb	374	3,627	0.72	0.65 - 0.81	< .001
> 5 ppb	753	6,961	0.76	0.70 - 0.82	< .001
TRICHLOROETHYLENE:					
n.d. - 1 ppb (ref)	6375	45,635	1.00	---	---
> 1 ppb - 5 ppb	513	4,091	0.90	0.82 - 0.99	< .03
> 5 ppb - 10 ppb	127	1,236	0.74	0.61 - 0.89	< .005
> 10 ppb	152	1,372	0.79	0.67 - 0.94	< .01
> 5 ppb	279	2,608	0.77	0.67 - 0.87	< .001
TETRACHLOROETHYLENE:					
n.d. - 1 ppb (ref)	5924	42,657	1.00	---	---
> 1 ppb - 5 ppb	929	6,737	0.99	0.92 - 1.01	NS
> 5 ppb - 10 ppb	273	2,472	0.80	0.70 - 0.90	< .001
> 10 ppb	41	468	0.63	0.46 - 0.87	< .01
> 5 ppb	314	2,940	0.77	0.68 - 0.87	< .001
DICHLOROETHYLENES:					
n.d. - 2 ppb (ref)	7056	51,224	1.00	---	---
> 2 ppb	111	1,110	0.73	0.60 - 0.88	< .005
n.d. - 1 ppb (ref)	6809	48,647	1.00	---	---
> 1 ppb	358	3,687	0.69	0.62 - 0.78	< .001
1,1,1-TRICHLOROETHANE:					
n.d. - 2 ppb (ref)	6899	49,184	1.00	---	---
> 2 ppb	268	3,150	0.61	0.53 - 0.69	< .001
n.d. - 1 ppb (ref)	6484	45,336	1.00	---	---
> 1 ppb	683	6,998	0.68	0.63 - 0.74	< .001

TABLE 12 (continued)
OUTCOME: Prematurity

CONTAMINANT LEVELS[1]	# CASES	# CONTROLS	ODDS RATIO	95% CONFIDENCE INTERVAL	2-TAIL P-VALUE[2]
CARBON TETRACHLORIDE:					
n.d. - 1 ppb (ref)	7130	52,025	1.00	---	---
> 1 ppb	37	309	0.87	0.62 - 1.2	NS
not detected (ref)	6945	49,910	1.00	---	---
detected	222	2,424	0.66	0.57 - 0.76	< .001
1,2-DICHLOROETHANE:					
n.d. - 1 ppb (ref)	7081	51,426	1.00	---	---
> 1 ppb	86	908	0.69	0.55 - 0.86	< .001
not detected (ref)	7055	51,117	1.00	---	---
detected	112	1,217	0.67	0.55 - 0.81	< .001
BENZENE:					
not detected (ref)	7005	50,813	1.00	---	---
detected	162	1,521	0.77	0.66 - 0.91	< .005
NITRATES:					
n.d. - 2 ppm (ref)	6537	44,872	1.00	---	---
> 2 ppm	630	7,462	0.58	0.53 - 0.63	< .001
TOTAL TRIHALOMETHANES:					
n.d.- 20 ppb (ref)	2679	19,766	1.00	---	
> 20 ppb - 40 ppb	307	2,936	0.77	0.68 - 0.88	< .001
> 40 ppb - 60 ppb	2318	15,657	1.09	1.03 - 1.2	< .005
> 60 ppb - 80 ppb	1262	9,913	0.94	0.87 - 1.01	< .09
> 80 ppb	601	4,062	1.09	0.99 - 1.2	< .08
n.d.- 15 ppb (ref)	2570	19,076	1.00	---	---
> 15 ppb - 50 ppb	1573	11,367	1.03	0.96 - 1.1	NS
> 50 ppb - 75 ppb	2156	15,344	1.04	0.98 - 1.1	NS
> 75 ppb	868	6,547	0.98	0.91 - 1.1	NS
SOURCE OF WATER SUPPLY[3]:					
ground water (ref)	2188	17,157	1.00	---	---
surface water	4142	29,078	1.12	1.06 - 1.2	< .001
mixture of sources	837	6,099	1.08	0.99 - 1.2	< .095

1 estimated average contaminant levels in drinking water during entire pregnancy.

ref = referent group　　n.d. = not detected
ppb = parts per billion　　ppm = parts per million

2 NS = the two-tail p-value is greater than 0.10.

3 Predominant (> 85%) source of the water supply during the first trimester. ("Mixture of sources" indicates that the water company's supply consisted of at least 15% from each source during the first trimester.)

TABLE 13
Adjusted Odds Ratios New Jersey Dept. of Health 1985-1988
OUTCOME: Prematurity

CASES = 6876 CONTROLS = 51,221

AVERAGE FIRST TRIMESTER CONTAMINANT LEVELS	ADJUSTED ODDS RATIO	95% CONFIDENCE INTERVAL	2-TAIL P-VALUE	"CRUDE" ODDS RATIO[1]
TOTAL A-280 VOLATILES:				
> 1 ppb - 5 ppb	0.98	0.91 - 1.04	NS	0.95
> 5 ppb - 10 ppb	0.86	0.77 - 0.97	< 0.15	0.78
> 10 ppb	0.99	0.88 - 1.1	NS	0.72
> 5 ppb	0.92	0.85 - 1.0	< 0.06	0.75
TRICHLOROETHYLENE:				
> 1 ppb - 5 ppb	0.97	0.88 - 1.1	NS	0.88
> 5 ppb - 10 ppb	1.09	0.90 - 1.3	NS	0.73
> 10 ppb	1.02	0.85 - 1.2	NS	0.80
> 5 ppb	1.05	0.92 - 1.2	NS	0.77
TETRACHLOROETHYLENE:				
> 1 ppb - 5 ppb	0.95	0.87 - 1.02	NS	0.99
> 5 ppb - 10 ppb	0.98	0.86 - 1.1	NS	0.80
> 10 ppb	0.90	0.65 - 1.3	NS	0.63
> 5 ppb	0.97	0.85 - 1.1	NS	0.78
The DICHLOROETHYLENES:				
> 2 ppb	1.04	0.85 - 1.3	NS	0.73
> 1 ppb	0.98	0.87 - 1.1	NS	0.70
1,1,1-TRICHLOROETHANE:				
> 2 ppb	0.90	0.78 - 1.02	< .10	0.61
> 1 ppb	0.96	0.88 - 1.05	NS	0.67
CARBON TETRACHLORIDE:				
> 1 ppb	1.11	0.79 - 1.60	NS	0.90
detected	0.91	0.79 - 1.06	NS	0.65
1,2-DICHLOROETHANE:				
> 1 ppb	0.84	0.66 - 1.05	NS	0.68
detected	0.84	0.69 - 1.03	< .095	0.66

TABLE 13 (continued)
OUTCOME: Prematurity

AVERAGE FIRST TRIMESTER CONTAMINANT LEVELS	ADJUSTED ODDS RATIO	95% CONFIDENCE INTERVAL	2-TAIL P-VALUE	"CRUDE" ODDS RATIO[1]
BENZENE:				
detected	0.99	0.83 - 1.2	NS	0.77
NITRATES:				
> 2 ppm	0.84	0.76 - 0.92	< .001	0.58
TOTAL TRIHALOMETHANES:				
> 20 ppb - 40 ppb	0.94	0.83 - 1.1	NS	0.76
> 40 ppb - 60 ppb	1.02	0.96 - 1.1	NS	1.11
> 60 ppb - 80 ppb	0.96	0.89 - 1.04	NS	0.94
> 80 ppb	1.04	0.94 - 1.1	NS	1.11
> 15 - 50 ppb	1.02	0.95 - 1.1	NS	1.04
> 50 - 75 ppb	0.98	0.92 - 1.05	NS	1.04
> 75 ppb	1.02	0.93 - 1.1	NS	1.00
WATER SOURCE:				
surface water	1.03	0.97 - 1.1	NS	1.12
mixture of sources	1.0	0.92 - 1.1	NS	1.08

1 The unadjusted odds ratio after removal of cases and controls with missing data on any of the factors included in the model.

ppb = parts per billion
ppm = parts per million
NS = two-tail p-value ≥ 0.10

Factors adjusted for in the model:

race of the mother (white/black/other)
maternal age (< 20, 20-34, ≥ 35)
maternal éducation (< 12, 12-15, ≥ 16)
parity (primipara/multipara)
previous adverse reproductive outcome (y/n)
"adequacy" of prenatal care (y/n) based on the trimester that care was first obtained and the number of visits per gestational age
sex of child

TABLE 14
Bivariate Odds Ratios. New Jersey Dept. of Health 1985-1988
OUTCOME: Very Low Birthweight

CASES = 905 CONTROLS = 52,334

CONTAMINANT LEVELS[1]	# CASES	# CONTROLS	ODDS RATIO	95% CONFIDENCE INTERVAL	2-TAIL P-VALUE[2]
A-280 TOTAL VOLATILE ORGANICS:					
n.d. - 1 ppb (ref)	647	34,991	1.00	---	---
> 1 ppb - 5 ppb	168	10,382	0.88	0.74 - 1.04	NS
> 5 ppb - 10 ppb	49	3,334	0.79	0.59 - 1.1	NS
> 10 ppb	41	3,627	0.61	0.45 - 0.84	< .005
> 5 ppb	90	6,961	0.70	0.56 - 0.87	< .005
TRICHLOROETHYLENE:					
n.d. - 1 ppb (ref)	814	45,635	1.00	---	---
> 1 ppb - 5 ppb	59	4,091	0.81	0.62 - 1.1	NS
> 5 ppb - 10 ppb	18	1,236	0.82	0.51 - 1.3	NS
> 10 ppb	14	1,372	0.57	0.34 - 0.97	< .04
> 5 ppb	32	2,608	0.69	0.47 - 0.99	< .05
TETRACHLOROETHYLENE:					
n.d. - 1 ppb (ref)	753	42,657	1.00	---	---
> 1 ppb - 5 ppb	122	6,737	1.03	0.85 - 1.2	NS
> 5 ppb - 10 ppb	21	2,472	0.48	0.31 - 0.74	< .001
> 10 ppb	9	468	1.09	0.56 - 2.1	NS
> 5 ppb	30	2,940	0.58	0.40 - 0.83	< .005
DICHLOROETHYLENES:					
n.d. - 2 ppb (ref)	890	51,224	1.00	---	---
> 2 ppb	15	1,110	0.78	0.47 - 1.3	NS
n.d. - 1 ppb (ref)	866	48,647	1.00	---	---
> 1 ppb	39	3,687	0.59	0.43 - 0.82	< .005
1,1,1-TRICHLOROETHANE:					
n.d. - 2 ppb (ref)	878	49,184	1.00	---	---
> 2 ppb	27	3,150	0.48	0.33 - 0.71	< .001
n.d. - 1 ppb (ref)	839	45,336	1.00	---	---
> 1 ppb	66	6,998	0.51	0.40 - 0.66	< .001

TABLE 14 (continued)
OUTCOME: Very Low Birthweight

CONTAMINANT LEVELS[1]	# CASES	# CONTROLS	ODDS RATIO	95% CONFIDENCE INTERVAL	2-TAIL P-VALUE[2]
CARBON TETRACHLORIDE:					
n.d. - 1 ppb (ref)	898	52,025	1.00	---	---
> 1 ppb	7	309	1.31	0.62 - 2.8	NS
not detected (ref)	882	49,910	1.00	---	---
detected	23	2,424	0.54	0.35 - 0.81	< .005
1,2-DICHLOROETHANE:					
n.d. - 1 ppb (ref)	898	51,426	1.00	---	---
> 1 ppb	7	908	0.44	0.21 - 0.93	< .035
not detected (ref)	895	51,117	1.00	---	---
detected	10	1,217	0.47	0.25 - 0.88	< .02
BENZENE:					
not detected (ref)	896	50,813	1.00	---	---
detected	9	1,521	0.34	0.17 - 0.65	< .005
NITRATES:					
n.d. - 2 ppm (ref)	847	44,872	1.00	---	---
> 2 ppm	58	7,462	0.41	0.32 - 0.54	< .001
TOTAL TRIHALOMETHANES:					
n.d.- 20 ppb (ref)	339	19,766	1.00	---	---
> 20 ppb - 40 ppb	35	2,936	0.70	0.49 - 0.99	< .045
> 40 ppb - 60 ppb	286	15,657	1.07	0.91 - 1.25	NS
> 60 ppb - 80 ppb	184	9,913	1.08	0.90 - 1.30	NS
> 80 ppb	61	4,062	0.88	0.67 - 1.15	NS
n.d.- 15 ppb (ref)	321	19,076	1.00	---	---
> 15 ppb - 50 ppb	192	11,367	1.0	0.84 - 1.2	NS
> 50 ppb - 75 ppb	301	15,344	1.17	0.99 - 1.4	< .06
> 75 ppb	91	6,547	0.83	0.65 - 1.04	NS
SOURCE OF WATER SUPPLY[3]:					
ground water (ref)	267	17,157	1.00	---	---
surface water	531	29,078	1.17	1.01 - 1.4	< .035
mixture of sources	107	6,099	1.13	0.90 - 1.4	NS

1 estimated average contaminant levels in drinking water during entire pregnancy.

ref = referent group　　n.d. = not detected
ppb = parts per billion　　ppm = parts per million

2 NS = the two-tail p-value is greater than 0.10.

3 Predominant (> 85%) source of the water supply during the first trimester. ("Mixture of sources" indicates that the water company's supply consisted of at least 15% from each source during the first trimester.)

TABLE 15
Adjusted Odds Ratios New Jersey Dept. of Health 1985-1988
OUTCOME: Very Low Birthweight

CASES = 775 **CONTROLS = 51,221**

AVERAGE FIRST TRIMESTER CONTAMINANT LEVELS	ADJUSTED ODDS RATIO	95% CONFIDENCE INTERVAL	2-TAIL P-VALUE	"CRUDE" ODDS RATIO[1]
TOTAL A-280 VOLATILES:				
> 1 ppb - 5 ppb	0.89	0.74 - 1.1	NS	0.87
> 5 ppb - 10 ppb	0.94	0.69 - 1.3	NS	0.85
> 10 ppb	0.89	0.61 - 1.3	NS	0.54
> 5 ppb	0.92	0.72 - 1.2	NS	0.69
TRICHLOROETHYLENE:				
> 1 ppb - 5 ppb	0.98	0.74 - 1.3	NS	0.89
> 5 ppb - 10 ppb	1.39	0.81 - 2.4	NS	0.73
> 10 ppb	0.73	0.39 - 1.4	NS	0.48
> 5 ppb	1.01	0.67 - 1.5	NS	0.60
TETRACHLOROETHYLENE:				
> 1 ppb - 5 ppb	0.97	0.79 - 1.2	NS	1.09
> 5 ppb - 10 ppb	0.65	0.40 - 1.04	< .08	0.48
> 10 ppb	1.49	0.66 - 3.4	NS	0.86
> 5 ppb	0.76	0.50 - 1.1	NS	0.54
The DICHLOROETHYLENES:				
> 2 ppb	1.21	0.66 - 2.2	NS	0.67
> 1 ppb	0.88	0.60 - 1.3	NS	0.51
1,1,1-TRICHLOROETHANE:				
> 2 ppb	0.92	0.61 - 1.4	NS	0.50
> 1 ppb	0.90	0.67 - 1.2	NS	0.51
CARBON TETRACHLORIDE:				
> 1 ppb	1.66	0.68 - 4.1	NS	1.11
detected	0.86	0.53 - 1.4	NS	0.49
1,2-DICHLOROETHANE:				
> 1 ppb	0.53	0.22 - 1.3	NS	0.37
detected	0.67	0.33 - 1.3	NS	0.44

TABLE 15 (continued)
OUTCOME: Very Low Birthweight

AVERAGE FIRST TRIMESTER CONTAMINANT LEVELS	ADJUSTED ODDS RATIO	95% CONFIDENCE INTERVAL	2-TAIL P-VALUE	"CRUDE" ODDS RATIO[1]
BENZENE:				
detected	0.39	0.14 - 0.86	< .015	0.26
NITRATES:				
> 2 ppm	0.72	0.53 - 0.97	< .035	0.40
TOTAL TRIHALOMETHANES:				
> 20 ppb - 40 ppb	0.87	0.58 - 1.3	NS	0.60
> 40 ppb - 60 ppb	1.03	0.86 - 1.2	NS	1.06
> 60 ppb - 80 ppb	1.13	0.93 - 1.4	NS	1.04
> 80 ppb	0.86	0.64 - 1.2	NS	0.91
> 15 - 50 ppb	1.05	0.86 - 1.3	NS	1.01
> 50 - 75 ppb	1.09	0.91 - 1.3	NS	1.11
> 75 ppb	0.93	0.72 - 1.2	NS	0.86
WATER SOURCE:				
surface water	1.07	0.91 - 1.3	NS	1.15
mixture of sources	1.01	0.79 - 1.3	NS	1.14

1 The unadjusted odds ratio after removal of cases and controls with missing data on any of the factors included in the model.

ppb = parts per billion
ppm = parts per million
NS = two-tail p-value ≥ 0.10

Factors adjusted for in the model:

race of the mother (white/black/other)
maternal age (< 20, 20-34, ≥ 35)
maternal éducation (< 12, 12-15, ≥ 16)
parity (primipara/multipara)
previous adverse reproductive outcome (y/n)
"adequacy" of prenatal care (y/n) based on the trimester that care was first obtained and the number of visits per gestational age
sex of child

TABLE 16
Bivariate Odds Ratios. New Jersey Dept. of Health 1985-1988
OUTCOME: Stillbirths

CASES = 594 CONTROLS = 52,334

CONTAMINANT LEVELS[1]	# CASES	# CONTROLS	ODDS RATIO	95% CONFIDENCE INTERVAL	2-TAIL P-VALUE[2]
A-280 TOTAL VOLATILE ORGANICS:					
n.d. - 1 ppb (ref)	429	35,968	1.00	---	---
> 1 ppb - 5 ppb	89	9,132	0.82	0.65 - 1.03	< .09
> 5 ppb - 10 ppb	35	3,091	0.95	0.67 - 1.3	NS
> 10 ppb	41	4,143	0.83	0.60 - 1.1	NS
> 5 ppb	76	7,234	0.88	0.69 - 1.1	NS
TRICHLOROETHYLENE:					
n.d. - 1 ppb (ref)	520	45,802	1.00	---	---
> 1 ppb - 5 ppb	49	3,790	1.14	0.85 - 1.5	NS
> 5 ppb - 10 ppb	14	1,169	1.05	0.62 - 1.8	NS
> 10 ppb	11	1,573	0.62	0.34 - 1.1	NS
> 5 ppb	25	2,742	0.80	0.54 - 1.2	NS
TETRACHLOROETHYLENE:					
n.d. - 1 ppb (ref)	491	42,924	1.00	---	---
> 1 ppb - 5 ppb	64	6,032	0.93	0.71 - 1.2	NS
> 5 ppb - 10 ppb	33	2,653	1.09	0.76 - 1.6	NS
> 10 ppb	6	725	0.72	0.32 - 1.6	NS
> 5 ppb	39	3,378	1.01	0.73 - 1.4	NS
DICHLOROETHYLENES:					
n.d. - 2 ppb (ref)	577	50,829	1.00	---	---
> 2 ppb	17	1,505	1.0	0.61 - 1.6	NS
n.d. - 1 ppb (ref)	564	48,479	1.00	---	---
> 1 ppb	30	3,855	0.67	0.46 - 0.97	< .035
1,1,1-TRICHLOROETHANE:					
n.d. - 2 ppb (ref)	567	49,072	1.00	---	---
> 2 ppb	27	3,262	0.72	0.49 - 1.06	< .095
n.d. - 1 ppb (ref)	523	44,378	1.00	---	---
> 1 ppb	71	7,956	0.76	0.59 - 0.97	< .03

TABLE 16 (continued)
OUTCOME: Stillbirths

CONTAMINANT LEVELS[1]	# CASES	# CONTROLS	ODDS RATIO	95% CONFIDENCE INTERVAL	2-TAIL P-VALUE[2]
CARBON TETRACHLORIDE:					
n.d. - 1 ppb (ref)	590	51,977	1.00	---	---
> 1 ppb	4	357	0.99	0.37 - 2.7	NS
not detected (ref)	576	50,341	1.00	---	---
detected	18	1,993	0.79	0.49 - 1.3	NS
1,2-DICHLOROETHANE:					
n.d. - 1 ppb (ref)	591	51,395	1.00	---	---
> 1 ppb	3	939	0.28	0.09 - 0.87	< .03
not detected (ref)	590	51,262	1.00	---	---
detected	4	1,072	0.32	0.12 - 0.87	< .03
BENZENE:					
not detected (ref)	584	50,925	1.00	---	---
detected	10	1,409	0.62	0.33 - 1.2	NS
NITRATES:					
n.d. - 2 ppm (ref)	547	44,872	1.00	---	---
> 2 ppm	47	7,462	0.52	0.38 - 0.70	< .001
TOTAL TRIHALOMETHANES:					
n.d.- 20 ppb (ref)	203	19,841	1.00	---	
> 20 ppb - 40 ppb	86	6,952	1.21	0.94 - 1.6	NS
> 40 ppb - 60 ppb	183	12,727	1.41	1.15 - 1.7	< .001
> 60 ppb - 80 ppb	93	9,004	1.01	0.79 - 1.3	NS
> 80 ppb	29	3,810	0.74	0.50 - 1.1	NS
n.d.- 15 ppb (ref)	191	19,015	1.00	---	---
> 15 ppb - 50 ppb	197	15,145	1.30	1.06 - 1.6	< .015
> 50 ppb - 75 ppb	149	12,523	1.19	0.96 - 1.5	NS
> 75 ppb	57	5,651	1.00	0.75 - 1.4	NS
SOURCE OF WATER SUPPLY[3]:					
ground water (ref)	158	17,157	1.00	---	---
surface water	366	29,078	1.37	1.13 - 1.7	< .002
mixture of sources	70	6,099	1.25	0.94 - 1.7	NS

1 estimated average contaminant levels in drinking water during entire pregnancy.

ref = referent group — n.d. = not detected
ppb = parts per billion — ppm = parts per million

2 NS = the two-tail p-value is greater than 0.10.

3 Predominant (> 85%) source of the water supply during the first trimester. ("Mixture of sources" indicates that the water company's supply consisted of at least 15% from each source during the first trimester.)

TABLE 17
Adjusted Odds Ratios New Jersey Dept. of Health 1985-1988
OUTCOME: Stillbirths

CASES = 417 CONTROLS = 51,480

AVERAGE FIRST TRIMESTER CONTAMINANT LEVELS	ADJUSTED ODDS RATIO	95% CONFIDENCE INTERVAL	2-TAIL P-VALUE	"CRUDE" ODDS RATIO[1]
TOTAL A-280 VOLATILES:				
> 1 ppb - 5 ppb	0.77	0.59 - 1.02	< .075	0.77
> 5 ppb - 10 ppb	0.97	0.63 - 1.5	NS	0.86
> 10 ppb	0.92	0.61 - 1.4	NS	0.73
> 5 ppb	0.94	0.69 - 1.3	NS	0.79
TRICHLOROETHYLENE:				
> 1 ppb - 5 ppb	0.97	0.66 - 1.4	NS	0.91
> 5 ppb - 10 ppb	1.63	0.89 - 3.0	NS	1.15
> 10 ppb	0.78	0.38 - 1.6	NS	0.63
> 5 ppb	1.11	0.70 - 1.8	NS	0.85
TETRACHLOROETHYLENE:				
> 1 ppb - 5 ppb	0.58	0.40 - 0.85	< .01	0.59
> 5 ppb - 10 ppb	1.02	0.66 - 1.6	NS	0.98
> 10 ppb	1.07	0.44 - 2.6	NS	0.82
> 5 ppb	1.03	0.70 - 1.5	NS	0.95
The DICHLOROETHYLENES:				
> 2 ppb	1.10	0.59 - 2.1	NS	0.83
> 1 ppb	0.73	0.46 - 1.2	NS	0.57
1,1,1-TRICHLOROETHANE:				
> 2 ppb	0.90	0.56 - 1.5	NS	0.68
> 1 ppb	0.91	0.67 - 1.2	NS	0.76
CARBON TETRACHLORIDE:				
> 1 ppb	1.32	0.30 - 3.9	NS	1.06
detected	0.63	0.31 - 1.3	NS	0.49
1,2-DICHLOROETHANE:				
> 1 ppb	0.15	0.01 - 0.83	< .015	0.13
detected	0.26	0.03 - 0.95	< .04	0.23

TABLE 17 (continued)
OUTCOME: Stillbirths

AVERAGE FIRST TRIMESTER CONTAMINANT LEVELS	ADJUSTED ODDS RATIO	95% CONFIDENCE INTERVAL	2-TAIL P-VALUE	"CRUDE" ODDS RATIO[1]
BENZENE:				
detected	0.42	0.11 - 1.1	< .055	0.35
NITRATES:				
> 2 ppm	0.73	0.50 - 1.05	< .07	0.53
TOTAL TRIHALOMETHANES:				
> 20 ppb - 40 ppb	1.16	0.85 - 1.6	NS	1.26
> 40 ppb - 60 ppb	1.34	1.05 - 1.7	< .02	1.49
> 60 ppb - 80 ppb	0.94	0.70 - 1.3	NS	0.97
> 80 ppb	0.72	0.44 - 1.2	NS	0.70
> 15 - 50 ppb	1.27	0.99 - 1.6	< .06	1.42
> 50 - 75 ppb	1.10	0.85 - 1.4	NS	1.19
> 75 ppb	0.99	0.69 - 1.4	NS	0.95
WATER SOURCE:				
surface water	1.26	1.0 - 1.6	≤ .05	1.40
mixture of sources	0.97	0.68 - 1.4	NS	1.04

1 The unadjusted odds ratio after removal of cases and controls with missing data on any of the factors included in the model.

ppb = parts per billion
ppm = parts per million
NS = two-tail p-value ≥ 0.10

Factors adjusted for in the model:

race of the mother (white/black/other)
maternal age (< 20, 20-34, ≥ 35)
maternal education (< 12, 12-15, ≥ 16)
parity (primipara/multipara)
previous adverse reproductive outcome (y/n)
"adequacy" of prenatal care (y/n) based on the trimester that care was first obtained and the number of visits per gestational age
sex of child

TABLE 18
Bivariate Odds Ratios. New Jersey Dept. of Health 1985-1988
OUTCOME: All Surveillance Malformations

CASES = 669 CONTROLS = 52,334

CONTAMINANT LEVELS[1]	# CASES	# CONTROLS	ODDS RATIO	95% CONFIDENCE INTERVAL	2-TAIL P-VALUE[2]
A-280 TOTAL VOLATILE ORGANICS:					
n.d. - 1 ppb (ref)	466	35,968	1.00	---	---
> 1 ppb - 5 ppb	134	9,132	1.13	0.93 - 1.4	NS
> 5 ppb - 10 ppb	24	3,091	0.61	0.40 - 0.91	< .02
> 10 ppb	45	4,143	0.84	0.62 - 1.1	NS
> 5 ppb	69	7,234	0.74	0.57 - 0.95	< .02
TRICHLOROETHYLENE:					
n.d. - 1 ppb (ref)	599	45,802	1.00	---	---
> 1 ppb - 5 ppb	32	3,790	0.65	0.45 - 0.92	< .02
> 5 ppb - 10 ppb	15	1,169	0.99	0.59 - 1.6	NS
> 10 ppb	23	1,573	1.12	0.74 - 1.7	NS
> 5 ppb	38	2,742	1.06	0.76 - 1.5	NS
TETRACHLOROETHYLENE:					
n.d. - 1 ppb (ref)	564	42,924	1.00	---	---
> 1 ppb - 5 ppb	72	6,032	0.91	0.71 - 1.2	NS
> 5 ppb - 10 ppb	25	2,653	0.72	0.48 - 1.1	NS
> 10 ppb	8	725	0.84	0.42 - 1.7	NS
> 5 ppb	33	3,378	0.74	0.52 - 1.06	NS
DICHLOROETHYLENES:					
n.d. - 2 ppb (ref)	649	50,829	1.00	---	---
> 2 ppb	20	1,505	1.04	0.67 - 1.6	NS
n.d. - 1 ppb (ref)	630	48,479	1.00	---	---
> 1 ppb	39	3,855	0.78	0.56 - 1.1	NS
1,1,1-TRICHLOROETHANE:					
n.d. - 2 ppb (ref)	646	49,072	1.00	---	---
> 2 ppb	23	3,262	0.54	0.35 - 0.81	< .005
n.d. - 1 ppb (ref)	573	44,378	1.00	---	---
> 1 ppb	96	7,956	0.93	0.75 - 1.2	NS

TABLE 18 (continued)
OUTCOME: <u>All Surveillance Malformations</u>

CONTAMINANT LEVELS[1]	# CASES	# CONTROLS	ODDS RATIO	95% CONFIDENCE INTERVAL	2-TAIL P-VALUE[2]
CARBON TETRACHLORIDE:					
n.d. - 1 ppb (ref)	662	51,977	1.00	---	---
> 1 ppb	7	357	1.54	0.73 - 3.3	NS
not detected (ref)	648	50,341	1.00	---	---
detected	21	1,993	0.82	0.53 - 1.3	NS
1,2-DICHLOROETHANE:					
n.d. - 1 ppb (ref)	657	51,395	1.00	---	---
> 1 ppb	12	939	1.00	0.56 - 1.8	NS
not detected (ref)	655	51,262	1.00	---	---
detected	14	1,072	1.02	0.60 - 1.7	NS
BENZENE:					
not detected (ref)	652	50,925	1.00	---	---
detected	17	1,409	0.94	0.58 - 1.5	NS
NITRATES:					
n.d. - 2 ppm (ref)	587	44,872	1.00	---	---
> 2 ppm	82	7,462	0.84	0.67 - 1.06	NS
TOTAL TRIHALOMETHANES:					
n.d.- 20 ppb (ref)	221	19,841	1.00	---	
> 20 ppb - 40 ppb	82	6,952	1.06	0.82 - 1.4	NS
> 40 ppb - 60 ppb	188	12,727	1.33	1.09 - 1.6	< .01
> 60 ppb - 80 ppb	111	9,004	1.11	0.88 - 1.4	NS
> 80 ppb	67	3,810	1.58	1.2 - 2.1	< .005
n.d.- 15 ppb (ref)	209	19,015	1.00	---	---
> 15 ppb - 50 ppb	207	15,145	1.24	1.03 - 1.5	< .03
> 50 ppb - 75 ppb	169	12,523	1.23	1.00 - 1.5	< .05
> 75 ppb	84	5,651	1.35	1.05 - 1.7	< .025
SOURCE OF WATER SUPPLY[3]:					
ground water (ref)	189	17,157	1.00	---	---
surface water	419	29,078	1.31	1.10 - 1.6	< .005
mixture of sources	61	6,099	0.91	0.68 - 1.2	NS

1 estimated average contaminant levels in drinking water during first trimester.

ref = referent group　　n.d. = not detected
ppb = parts per billion　　ppm = parts per million

2 NS: the two-tail p-value is greater than 0.10.

3 Predominant (> 85%) source of the water supply during the first trimester. ("Mixture of sources" indicates that the water company's supply consisted of at least 15% from each source during the first trimester.)

TABLE 19
Adjusted Odds Ratios New Jersey Dept. of Health 1985-1988
OUTCOME: All Surveillance Malformations

CASES = 595 CONTROLS = 51,221

AVERAGE FIRST TRIMESTER CONTAMINANT LEVELS	ADJUSTED ODDS RATIO	95% CONFIDENCE INTERVAL	2-TAIL P-VALUE	"CRUDE" ODDS RATIO[1]
TOTAL A-280 VOLATILES:				
> 1 ppb - 5 ppb	1.18	0.96 - 1.4	NS	1.17
> 5 ppb - 10 ppb	0.64	0.41 - 1.0	< .05	0.60
> 10 ppb	0.91	0.65 - 1.3	NS	0.82
> 5 ppb	0.79	0.60 - 1.04	< .10	0.73
TRICHLOROETHYLENE:				
> 1 ppb - 5 ppb	0.76	0.53 - 1.1	NS	0.73
> 5 ppb - 10 ppb	1.23	0.72 - 2.1	NS	1.02
> 10 ppb	1.07	0.67 - 1.7	NS	1.05
> 5 ppb	1.13	0.80 - 1.6	NS	1.04
TETRACHLOROETHYLENE:				
> 1 ppb - 5 ppb	0.94	0.72 - 1.2	NS	0.91
> 5 ppb - 10 ppb	0.72	0.47 - 1.1	NS	0.72
> 10 ppb	1.14	0.56 - 2.3	NS	0.94
> 5 ppb	0.80	0.55 - 1.2	NS	0.76
The DICHLOROETHYLENES:				
> 2 ppb	1.15	0.71 - 1.9	NS	1.0
> 1 ppb	0.86	0.61 - 1.2	NS	0.77
1,1,1-TRICHLOROETHANE:				
> 2 ppb	0.59	0.38 - 0.92	< .025	0.52
> 1 ppb	0.97	0.77 - 1.2	NS	0.93
CARBON TETRACHLORIDE:				
> 1 ppb	1.44	0.64 - 3.3	NS	1.47
detected	0.88	0.55 - 1.4	NS	0.82
1,2-DICHLOROETHANE:				
> 1 ppb	0.98	0.54 - 1.8	NS	1.02
detected	1.03	0.59 - 1.8	NS	1.06

TABLE 19 (continued)
OUTCOME: All Surveillance Malformations

AVERAGE FIRST TRIMESTER CONTAMINANT LEVELS	ADJUSTED ODDS RATIO	95% CONFIDENCE INTERVAL	2-TAIL P-VALUE	"CRUDE" ODDS RATIO[1]
BENZENE:				
detected	0.91	0.54 - 1.5	NS	0.92
NITRATES:				
> 2 ppm	0.96	0.75 - 1.2	NS	0.85
TOTAL TRIHALOMETHANES:				
> 20 ppb - 40 ppb	0.96	0.73 - 1.3	NS	1.03
> 40 ppb - 60 ppb	1.24	1.0 - 1.5	< .05	1.34
> 60 ppb - 80 ppb	0.99	0.77 - 1.3	NS	1.05
> 80 ppb	1.53	1.14 - 2.1	< .01	1.54
> 15 - 50 ppb	1.11	0.90 - 1.4	NS	1.21
> 50 - 75 ppb	1.11	0.89 - 1.4	NS	1.20
> 75 ppb	1.32	1.01 - 1.7	< .05	1.33
WATER SOURCE:				
surface water	1.18	0.98 - 1.4	< .085	1.29
mixture of sources	0.89	0.66 - 1.2	NS	0.94

1 The unadjusted odds ratio after removal of cases and controls with missing data on any of the factors included in the model.

ppb = parts per billion
ppm = parts per million
NS = two-tail p-value ≥ 0.10

Factors adjusted for in the model:

- race of the mother (white/black/other)
- maternal age (< 20, 20-34, ≥ 35)
- maternal education (< 12, 12-15, ≥ 16)
- parity (primipara/multipara)
- previous adverse reproductive outcome (y/n)
- "adequacy" of prenatal care (y/n) based on the trimester that care was first obtained and the number of visits per gestational age
- sex of child

TABLE 20
Bivariate Odds Ratios. New Jersey Dept. of Health 1985-1988
OUTCOME: CNS Defects

CASES = 118 CONTROLS = 52,334

CONTAMINANT LEVELS[1]	# CASES	# CONTROLS	ODDS RATIO	95% CONFIDENCE INTERVAL	2-TAIL P-VALUE[2]
A-280 TOTAL VOLATILE ORGANICS:					
n.d. - 1 ppb (ref)	82	35,968	1.00	---	---
> 1 ppb - 5 ppb	24	9,132	1.15	0.73 - 1.8	NS
> 5 ppb - 10 ppb	4	3,091	0.57	0.21 - 1.6	NS
> 10 ppb	8	4,143	0.85	0.41 - 1.8	NS
> 5 ppb	12	7,234	0.73	0.40 - 1.3	NS
TRICHLOROETHYLENE:					
n.d. - 1 ppb (ref)	104	45,802	1.00	---	---
> 1 ppb - 5 ppb	8	3,790	0.93	0.45 - 1.9	NS
> 5 ppb - 10 ppb	0	1,169	---	---	---
> 10 ppb	6	1,573	1.68	0.70 - 4.0	NS
> 5 ppb	6	2,742	0.96	0.42 - 2.2	NS
TETRACHLOROETHYLENE:					
n.d. - 1 ppb (ref)	99	42,924	1.00	---	---
> 1 ppb - 5 ppb	14	6,032	1.01	0.57 - 1.8	NS
> 5 ppb - 10 ppb	4	2,653	0.65	0.24 - 1.8	NS
> 10 ppb	1	725	0.60	0.08 - 4.3	NS
> 5 ppb	5	3,378	0.64	0.26 - 1.6	NS
DICHLOROETHYLENES:					
n.d. - 2 ppb (ref)	112	50,829	1.00	---	---
> 2 ppb	6	1,505	1.81	0.80 - 4.1	NS
n.d. - 1 ppb (ref)	108	48,479	1.00	---	---
> 1 ppb	10	3,855	1.16	0.61 - 1.2	NS
1,1,1-TRICHLOROETHANE:					
n.d. - 2 ppb (ref)	116	49,072	1.00	---	---
> 2 ppb	2	3,262	0.26	0.06 - 1.05	< .06
n.d. - 1 ppb (ref)	99	44,378	1.00	---	---
> 1 ppb	19	7,956	1.07	0.66 - 1.8	NS

TABLE 20 (continued)
OUTCOME: CNS Defects

CONTAMINANT LEVELS[1]	# CASES	# CONTROLS	ODDS RATIO	95% CONFIDENCE INTERVAL	2-TAIL P-VALUE[2]
CARBON TETRACHLORIDE:					
n.d. - 1 ppb (ref)	115	51,977	1.00	---	---
> 1 ppb	3	357	3.80	1.2 - 12.0	< .025
not detected (ref)	113	50,341	1.00	---	---
detected	5	1,993	1.12	0.40 - 2.8	NS
1,2-DICHLOROETHANE:					
n.d. - 1 ppb (ref)	117	51,395	1.00	---	---
> 1 ppb	1	939	0.47	0.07 - 3.4	NS
not detected (ref)	117	51,262	1.00	---	---
detected	1	1,072	0.41	0.06 - 2.9	NS
BENZENE:					
not detected (ref)	115	50,925	1.00	---	---
detected	3	1,409	0.94	0.30 - 3.0	NS
NITRATES:					
n.d. - 2 ppm (ref)	98	44,872	1.00	---	---
> 2 ppm	20	7,462	1.23	0.76 - 2.0	NS
TOTAL TRIHALOMETHANES:					
n.d.- 20 ppb (ref)	36	19,841	1.00	---	---
> 20 ppb - 40 ppb	13	6,952	1.03	0.55 - 1.9	NS
> 40 ppb - 60 ppb	30	12,727	1.30	0.80 - 2.1	NS
> 60 ppb - 80 ppb	21	9,004	1.29	0.75 - 2.2	NS
> 80 ppb	18	3,810	2.60	1.48 - 4.6	< .001
n.d.- 15 ppb (ref)	34	19,015	1.00	---	---
> 15 ppb - 50 ppb	32	15,145	1.18	0.73 - 1.92	NS
> 50 ppb - 75 ppb	31	12,523	1.38	0.85 - 2.25	NS
> 75 ppb	21	5,651	2.08	1.21 - 3.58	< .01
SOURCE OF WATER SUPPLY[3]:					
ground water (ref)	29	17,157	1.00	---	---
surface water	73	29,078	1.49	0.97 - 2.3	< .075
mixture of sources	16	6,099	1.55	0.84 - 2.9	NS

1 estimated average contaminant levels in drinking water during first trimester.

ref = referent group n.d. = not detected
ppb = parts per billion ppm = parts per million

2 NS: the two-tail p-value is greater than 0.10.

3 Predominant (> 85%) source of the water supply during the first trimester. ("Mixture of sources" indicates that the water company's supply consisted of a least 15% from each source during the first trimester.)

TABLE 21

OUTCOME: Central Nervous System Defects

CASES = 102 CONTROLS = 51,221

AVERAGE FIRST TRIMESTER CONTAMINANT LEVELS	ADJUSTED ODDS RATIO	95% CONFIDENCE INTERVAL	2-TAIL P-VALUE	"CRUDE" ODDS RATIO[1]
TOTAL A-280 VOLATILES:				
> 1 ppb - 5 ppb	1.34	0.83 - 2.2	NS	1.28
> 5 ppb - 10 ppb	0.77	0.28 - 2.1	NS	0.69
> 10 ppb	1.14	0.55 - 2.4	NS	1.03
TRICHLOROETHYLENE:				
> 1 ppb - 5 ppb	1.20	0.58 - 2.5	NS	1.10
> 5 ppb	1.13	0.80 - 1.6	NS	1.04
TETRACHLOROETHYLENE:				
> 1 ppb - 5 ppb	1.35	0.76 - 2.4	NS	1.21
> 5 ppb - 10 ppb	0.79	0.29 - 3.3	NS	0.78
> 10 ppb	0.91	0.13 - 6.6	NS	0.71
> 5 ppb	0.81	0.33 - 2.0	NS	0.77
The DICHLOROETHYLENES:				
> 2 ppb	2.52	1.09 - 5.8	< .035	2.13
> 1 ppb	1.56	0.80 - 3.1	NS	1.37
1,1,1-TRICHLOROETHANE:				
> 2 ppb	0.36	0.09 - 1.5	NS	0.30
> 1 ppb	1.16	0.69 - 2.0	NS	1.12
CARBON TETRACHLORIDE:				
> 1 ppb	4.64	0.93 -14.2	< .065	4.48
detected	1.49	0.47 - 3.6	NS	1.31
1,2-DICHLOROETHANE:				
> 1 ppb	0.48	0.07 - 3.5	NS	0.54
detected	0.43	0.06 - 3.1	NS	0.47

TABLE 21 (Continued)
OUTCOME: Central Nervous System Defects

AVERAGE FIRST TRIMESTER CONTAMINANT LEVELS	ADJUSTED ODDS RATIO	95% CONFIDENCE INTERVAL	2-TAIL P-VALUE	"CRUDE" ODDS RATIO[1]
BENZENE:				
detected	1.06	0.21 - 3 2	NS	1.07
NITRATES:				
> 2 ppm	1.54	0.91 - 2.6	NS	1.29
TOTAL TRIHALOMETHANES:				
> 20 ppb - 40 ppb	0.76	0.38 - 1.5	NS	0 94
> 40 ppb - 60 ppb	1.03	0 61 - 1.7	NS	1.27
> 60 ppb - 80 ppb	0.79	0.42 - 1.5	NS	0 93
> 80 ppb	2.52	1.40 - 4.5	< .005	2.66
> 15 - 50 ppb	0.87	0.51 - 1.5	NS	1.09
> 50 - 75 ppb	0.96	0.56 - 1.7	NS	1.16
> 75 ppb	2.06	1.17 - 3.6	< .015	2.15
WATER SOURCE:				
surface water	1.11	0.69 - 1.8	NS	1.35
mixture of sources	1.63	0.87 - 3.0	NS	1.74

1 The unadjusted odds ratio after removal of cases and controls with missing data on any of the factors included in the model.

ppb = parts per billion
ppm = parts per million
ns = two-tail p-value ≥ 0.10

Factors adjusted for in the model:
- race of the mother (white/black/other)
- maternal age (< 20, 20-34, ≥ 35)
- maternal education (< 12, 12-15, ≥ 16)
- parity (primipara/multipara)
- previous adverse reproductive outcome (y/n)
- "adequacy" of prenatal care (y/n) based on the trimester that care was first obtained and the number of visits per gestational age
- sex of child

TABLE 22
Bivariate Odds Ratios. New Jersey Dept. of Health 1985-1988
OUTCOME: CNS - Single Defect

CASES = 95 CONTROLS = 52,334

CONTAMINANT LEVELS[1]	# CASES	# CONTROLS	ODDS RATIO	95% CONFIDENCE INTERVAL	2-TAIL P-VALUE[2]
A-280 TOTAL VOLATILE ORGANICS:					
n.d. - 1 ppb (ref)	69	35,968	1.00	---	---
> 1 ppb - 5 ppb	16	9,132	0.91	0.53 - 1.6	NS
> 5 ppb - 10 ppb	4	3,091	0.67	0.25 - 1.9	NS
> 10 ppb	6	4,143	0.75	0.33 - 1.7	NS
> 5 ppb	10	7,234	0.72	0.37 - 1.4	NS
TRICHLOROETHYLENE:					
n.d. - 1 ppb (ref)	86	45,802	1.00	---	---
> 1 ppb - 5 ppb	5	3,790	0.70	0.29 - 0.98	NS
> 5 ppb - 10 ppb	0	1,169	---	---	---
> 10 ppb	4	1,573	1.35	0.42 - 3.8	NS
> 5 ppb	4	2,742	0.78	0.29 - 2.1	NS
TETRACHLOROETHYLENE:					
n.d. - 1 ppb (ref)	80	42,924	1.00	---	---
> 1 ppb - 5 ppb	11	6,032	0.98	0.52 - 1.8	NS
> 5 ppb - 10 ppb	3	2,653	0.61	0.19 - 1.9	NS
> 10 ppb	1	725	0.74	0.10 - 5.3	NS
> 5 ppb	4	3,378	0.64	0.23 - 1.7	NS
DICHLOROETHYLENES:					
n.d. - 2 ppb (ref)	90	50,829	1.00	---	---
> 2 ppb	5	1,505	1.88	0.76 - 4.6	NS
n.d. - 1 ppb (ref)	87	48,479	1.00	---	---
> 1 ppb	8	3,855	1.16	0.56 - 2.4	NS
1,1,1-TRICHLOROETHANE:					
n.d. - 2 ppb (ref)	93	49,072	1.00	---	---
> 2 ppb	2	3,262	0.32	0.08 - 1.3	NS
n.d. - 1 ppb (ref)	82	44,378	1.00	---	---
> 1 ppb	13	7,956	0.88	0.49 - 1.6	NS

TABLE 22 (continued)
OUTCOME: CNS - Single Defect

CONTAMINANT LEVELS[1]	# CASES	# CONTROLS	ODDS RATIO	95% CONFIDENCE INTERVAL	2-TAIL P-VALUE[2]
CARBON TETRACHLORIDE:					
n.d. - 1 ppb (ref)	93	51,977	1.00	---	---
> 1 ppb	2	357	3.13	0.77 - 12.8	NS
not detected (ref)	92	50,341	1.00	---	---
detected	3	1,993	0.82	0.26 - 2.6	NS
1,2-DICHLOROETHANE:					
n.d. - 1 ppb (ref)	95	51,395	1.00	---	---
> 1 ppb	0	939	---	---	---
not detected (ref)	95	51,262	1.00	---	---
detected	0	1,072	---	---	---
BENZENE:					
not detected (ref)	93	50,925	1.00	---	---
detected	2	1,409	0.78	0.19 - 3.2	NS
NITRATES:					
n.d. - 2 ppm (ref)	81	44,872	1.00	---	---
> 2 ppm	14	7,462	1.04	0.59 - 1.8	NS
TOTAL TRIHALOMETHANES:					
n.d.- 20 ppb (ref)	29	19,841	1.00	---	---
> 20 ppb - 40 ppb	9	6,952	0.89	0.42 - 1.9	NS
> 40 ppb - 60 ppb	25	12,727	1.34	0.79 - 2.3	NS
> 60 ppb - 80 ppb	17	9,004	1.29	0.71 - 2.4	NS
> 80 ppb	15	3,810	2.69	1.44 - 5.0	< .005
n.d.- 15 ppb (ref)	29	19,015	1.00	---	---
> 15 ppb - 50 ppb	23	15,145	1.00	0.58 - 1.7	NS
> 50 ppb - 75 ppb	26	12,523	1.36	0.80 - 2.3	NS
> 75 ppb	17	5,651	1.97	1.08 - 3.6	< .03
SOURCE OF WATER SUPPLY[3]:					
ground water (ref)	25	17,157	1.00	---	---
surface water	58	29,078	1.37	0.86 - 2.2	NS
mixture of sources	12	6,099	1.35	0.68 - 2.7	NS

1 estimated average contaminant levels in drinking water during first trimester.

ref = referent group
ppb = parts per billion
n.d. = not detected
ppm = parts per million

2 NS: the two-tail p-value is greater than 0.10.

3 Predominant (> 85%) source of the water supply during the first trimester. ("Mixture of sources" indicates that the water company's supply consisted of at least 15% from each source during the first trimester.)

TABLE 23

Bivariate Odds Ratios. New Jersey Dept. of Health 1985-1988

OUTCOME: CNS - Multiple

CASES = 23 CONTROLS = 52,334

CONTAMINANT LEVELS[1]	# CASES	# CONTROLS	ODDS RATIO	95% CONFIDENCE INTERVAL	2-TAIL P-VALUE[2]
A-280 TOTAL VOLATILE ORGANICS:					
n.d. - 1 ppb (ref)	13	35,968	1.00	---	---
> 1 ppb - 5 ppb	8	9,132	2.42	1.0 - 1.01	< .05
> 5 ppb - 10 ppb	0	3,091	---	---	---
> 10 ppb	2	4,143	1.34	0.21 - 6.2	NS
> 5 ppb	2	7,234	0.77	0.17 - 3.4	NS
TRICHLOROETHYLENE:					
n.d. - 1 ppb (ref)	18	45,802	1.00	---	---
> 1 ppb - 5 ppb	3	3,790	2.01	0.59 - 6.8	NS
> 5 ppb - 10 ppb	0	1,169	---	---	---
> 10 ppb	2	1,573	3.24	0.52 - 14.5	< .10
> 5 ppb	2	2,742	1.86	0.43 - 8	NS
TETRACHLORO-ETHYLENE:					
n.d. - 1 ppb (ref)	19	42,924	1.00	---	---
> 1 ppb - 5 ppb	3	6,032	1.12	0.33 - 3.8	NS
> 5 ppb - 10 ppb	1	2,653	0.85	0.04 - 6	NS
> 10 ppb	0	725	---	---	---
> 5 ppb	1	3,378	0.67	0.09 - 5	NS
DICHLOROETHYLENES:					
n.d. - 2 ppb (ref)	22	50,829	1.00	---	---
> 2 ppb	1	1,505	1.54	0.21 - 11.4	NS
n.d. - 1 ppb (ref)	21	48,479	1.00	---	---
> 1 ppb	2	3,855	1.20	0.28 - 5.1	NS
1,1,1-TRICHLOROETHANE:					
n.d. - 2 ppb (ref)	23	49,072	1.00	---	---
> 2 ppb	0	3,262	---	---	---
n.d. - 1 ppb (ref)	17	44,378	1.00	---	---
> 1 ppb	6	7,956	1.97	0.78 - 5	NS

TABLE 23 (continued)
OUTCOME: CNS - Multiple

CONTAMINANT LEVELS[1]	# CASES	# CONTROLS	ODDS RATIO	95% CONFIDENCE INTERVAL	2-TAIL P-VALUE[2]
CARBON TETRACHLORIDE:					
n.d. - 1 ppb (ref)	22	51,977	1.00	---	---
> 1 ppb	1	357	6.62	0.89 - 49.2	< .07
not detected (ref)	21	50,341	1.00	---	---
detected	2	1,993	2.41	0.56 - 10.3	NS
1,2-DICHLOROETHANE:					
n.d. - 1 ppb (ref)	22	51,395	1.00	---	---
> 1 ppb	1	939	2.49	0.34 - 18.5	NS
not detected (ref)	22	51,262	1.00	---	---
detected	1	1,072	2.17	0.29 - 16.1	NS
BENZENE:					
not detected (ref)	22	50,925	1.00	---	---
detected	1	1,409	1.64	0.22 - 12.2	NS
NITRATES:					
n.d. - 2 ppm (ref)	17	44,872	1.00	---	---
> 2 ppm	6	7,462	2.12	0.84 - 5.4	NS
TOTAL TRIHALOMETHANES:					
n.d.- 20 ppb (ref)	7	19,841	1.00	---	---
> 20 ppb - 40 ppb	4	6,952	1.63	0.48 - 5.6	NS
> 40 ppb - 60 ppb	5	12,727	1.11	0.35 - 3.5	NS
> 60 ppb - 80 ppb	4	9,004	1.26	0.37 - 4.3	NS
> 80 ppb	3	3,810	2.23	0.58 - 8.6	NS
n.d.- 15 ppb (ref)	5	19,015	1.00	---	---
> 15 ppb - 50 ppb	9	15,145	2.26	0.76 - 6.7	NS
> 50 ppb - 75 ppb	5	12,523	1.52	0.44 - 5.2	NS
> 75 ppb	4	5,651	2.69	0.72 - 10.0	NS
SOURCE OF WATER SUPPLY[3]:					
ground water (ref)	4	17,157	1.00	---	---
surface water	15	29,078	2.21	0.73 - 6.7	NS
mixture of sources	4	6,099	2.81	0.70 - 11.3	NS

1 estimated average contaminant levels in drinking water during first trimester.

ref = referent group n.d. = not detected
ppb = parts per billion ppm = parts per million

2 NS: the two-tail p-value is greater than 0.10.

3 Predominant (> 85%) source of the water supply during the first trimester. ("Mixture of sources" indicates that the water company's supply consisted of at least 15% from each source during the first trimester.)

TABLE 24
Bivariate Odds Ratios. New Jersey Dept. of Health 1985-1988
OUTCOME: Neural Tube Defects

CASES = 56 CONTROLS = 52,334

CONTAMINANT LEVELS[1]	# CASES	# CONTROLS	ODDS RATIO	95% CONFIDENCE INTERVAL	2-TAIL P-VALUE[2]
A-280 TOTAL VOLATILE ORGANICS:					
n.d. - 1 ppb (ref)	36	35,968	1.00	---	---
> 1 ppb - 5 ppb	11	9,1322	1.20	0.61 - 2.4	NS
> 5 ppb - 10 ppb	3	3,091	0.97	0.30 - 3.2	NS
> 10 ppb	6	4,143	1.45	0.61 - 3.4	NS
> 5 ppb	9	7,234	1.24	0.60 - 2.6	NS
TRICHLOROETHYLENE:					
n.d. - 1 ppb (ref)	46	45,802	1.00	---	---
> 1 ppb - 5 ppb	6	3,790	1.58	0.67 - 3.7	NS
> 5 ppb - 10 ppb	0	1,169	---	---	---
> 10 ppb	4	1,573	2.53	0.80 - 7.3	< .07
> 5 ppb	4	2,742	1.45	0.52 - 4.0	NS
TETRACHLOROETHYLENE:					
n.d. - 1 ppb (ref)	44	42,924	1.00	---	---
> 1 ppb - 5 ppb	8	6,032	1.29	0.61 - 2.8	NS
> 5 ppb - 10 ppb	3	2,653	1.10	0.34 - 3.6	NS
> 10 ppb	1	725	1.35	0.19 - 9.8	NS
> 5 ppb	4	3,378	1.16	0.42 - 3.2	NS
DICHLOROETHYLENES:					
n.d. - 2 ppb (ref)	52	50,829	1.00	---	---
> 2 ppb	4	1,505	2.60	0.94 - 7.2	< .07
n.d. - 1 ppb (ref)	48	48,479	1.00	---	---
> 1 ppb	8	3,855	2.10	0.99 - 4.4	< .055
1,1,1-TRICHLOROETHANE:					
n.d. - 2 ppb (ref)	55	49,072	1.00	---	---
> 2 ppb	1	3,262	0.27	0.04 - 2.0	NS
n.d. - 1 ppb (ref)	46	44,378	1.00	---	---
> 1 ppb	10	7,956	1.21	0.61 - 2.4	NS

TABLE 24 (continued)
OUTCOME: Neural Tube Defects

CONTAMINANT LEVELS[1]	# CASES	# CONTROLS	ODDS RATIO	95% CONFIDENCE INTERVAL	2-TAIL P-VALUE[2]
CARBON TETRACHLORIDE:					
n.d. - 1 ppb (ref)	54	51,977	1.00	---	---
> 1 ppb	2	357	5.39	1.31 - 22.2	< .025
not detected (ref)	52	50,341	1.00	---	---
detected	4	1,993	1.94	0.70 - 5.4	NS
1,2-DICHLOROETHANE:					
n.d. - 1 ppb (ref)	55	51,395	1.00	---	---
> 1 ppb	1	939	1.00	0.14 - 7.2	NS
not detected (ref)	55	51,262	1.00	---	---
detected	1	1,072	0.87	0.12 - 6.3	NS
BENZENE:					
not detected (ref)	53	50,925	1.00	---	---
detected	3	1,409	2.05	0.64 - 6.6	NS
NITRATES:					
n.d. - 2 ppm (ref)	43	44,872	1.00	---	---
> 2 ppm	13	7,463	1.82	0.98 - 3.4	< .06
TOTAL TRIHALOMETHANES:					
n.d.- 20 ppb (ref)	14	19,841	1.00	---	
> 20 ppb - 40 ppb	9	6,952	1.84	0.79 - 4.2	NS
> 40 ppb - 60 ppb	16	12,727	1.78	0.87 - 3.7	NS
> 60 ppb - 80 ppb	9	9,004	1.42	0.61 - 3.3	NS
> 80 ppb	8	3,810	2.98	1.25 - 7.1	< .015
n.d.- 15 ppb (ref)	13	19,015	1.00	---	---
> 15 ppb - 50 ppb	19	15,145	1.84	0.91 - 3.7	NS
> 50 ppb - 75 ppb	15	12,523	1.75	0.83 - 3.7	NS
> 75 ppb	9	5,651	2.33	1.0 - 5.5	< .055
SOURCE OF WATER SUPPLY[3]:					
ground water (ref)	12	17,157	1.00	---	---
surface water	34	29,078	1.67	0.83 - 3.4	NS
mixture of sources	10	6,099	2.34	0.94 - 5.8	< .075

1 estimated average contaminant levels in drinking water during first trimester.

ref = referent group
ppb = parts per billion
n.d. = not detected
ppm = parts per million

2 NS: the two-tail p-value is greater than 0.10.

3 Predominant (> 85%) source of the water supply during the first trimester. ("Mixture of sources" indicates that the water company's supply consisted of at least 15% from each source during the first trimester.)

TABLE 25
Bivariate Odds Ratios. New Jersey Dept. of Health 1985-1988
OUTCOME: NTD - Single

CASES = 46 CONTROLS = 52,334

CONTAMINANT LEVELS[1]	# CASES	# CONTROLS	ODDS RATIO	95% CONFIDENCE INTERVAL	2-TAIL P-VALUE[2]
A-280 TOTAL VOLATILE ORGANICS:					
n.d. - 1 ppb (ref)	33	35,968	1.00	---	---
> 1 ppb - 5 ppb	5	9,1322	0.60	0.23 - 1.5	NS
> 5 ppb - 10 ppb	3	3,091	1.06	0.32 - 3.5	NS
> 10 ppb	5	4,143	1.32	0.51 - 3.4	NS
> 5 ppb	8	7,234	1.21	0.56 - 2.6	NS
TRICHLOROETHYLENE:					
n.d. - 1 ppb (ref)	39	45,802	1.00	---	---
> 1 ppb - 5 ppb	4	3,790	1.24	0.44 - 3.58	NS
> 5 ppb - 10 ppb	0	1,169	---	---	---
> 10 ppb	3	1,573	2.24	0.60 - 7.6	NS
> 5 ppb	3	2,742	1.29	0.40 - 4.2	NS
TETRACHLOROETHYLENE:					
n.d. - 1 ppb (ref)	37	42,924	1.00	---	---
> 1 ppb - 5 ppb	6	6,032	1.15	0.49 - 2.7	NS
> 5 ppb - 10 ppb	2	2,653	0.87	0.21 - 3.6	NS
> 10 ppb	1	725	1.60	0.22 - 11.7	NS
> 5 ppb	3	3,378	1.03	0.32 - 3.3	NS
DICHLOROETHYLENES:					
n.d. - 2 ppb (ref)	42	50,829	1.00	---	---
> 2 ppb	4	1,505	3.22	1.15 - 9.0	< .03
n.d. - 1 ppb (ref)	39	48,479	1.00	---	---
> 1 ppb	7	3,855	2.26	1.01 - 5.1	< .05
1,1,1-TRICHLOROETHANE:					
n.d. - 2 ppb (ref)	45	49,072	1.00	---	---
> 2 ppb	1	3,262	0.33	0.05 - 2.4	NS
n.d. - 1 ppb (ref)	41	44,378	1.00	---	---
> 1 ppb	5	7,956	0.68	0.27 - 1.7	NS

TABLE 25 (continued)
OUTCOME: NTD - Single

CONTAMINANT LEVELS[1]	# CASES	# CONTROLS	ODDS RATIO	95% CONFIDENCE INTERVAL	2-TAIL P-VALUE[2]
CARBON TETRACHLORIDE:					
n.d. - 1 ppb (ref)	44	51,977	1.00	---	---
> 1 ppb	2	357	6.62	1.6 - 27.4	< .01
not detected (ref)	43	50,341	1.00	---	---
detected	3	1,993	1.76	0.55 - 5.7	NS
1,2-DICHLOROETHANE:					
n.d. - 1 ppb (ref)	46	51,395	1.00	---	---
> 1 ppb	0	939	---	---	---
not detected (ref)	46	51,262	1.00	---	---
detected	0	1,072	---	---	---
BENZENE:					
not detected (ref)	44	50,925	1.00	---	---
detected	2	1,409	1.64	0.40 - 6.8	NS
NITRATES:					
n.d. - 2 ppm (ref)	36	44,872	1.00	---	---
> 2 ppm	10	7,462	1.67	0.83 - 3.4	NS
TOTAL TRIHALOMETHANES:					
n.d.- 20 ppb (ref)	11	19,841	1.00	---	
> 20 ppb - 40 ppb	7	6,952	1.82	0.70 - 4.7	NS
> 40 ppb - 60 ppb	13	12,727	1.84	0.83 - 4.1	NS
> 60 ppb - 80 ppb	8	9,004	1.60	0.64 - 4.0	NS
> 80 ppb	7	3,810	3.31	1.28 - 8.6	< .015
n.d.- 15 ppb (ref)	11	19,015	1.00	---	---
> 15 ppb - 50 ppb	13	15,145	1.48	0.66 - 3.3	NS
> 50 ppb - 75 ppb	15	12,523	2.07	0.95 - 4.5	< .07
> 75 ppb	7	5,651	2.14	0.83 - 5.5	NS
SOURCE OF WATER SUPPLY[3]:					
ground water (ref)	10	17,157	1.00	---	---
surface water	28	29,078	1.65	0.80 - 3.4	NS
mixture of sources	8	6,099	2.24	0.89 - 5.7	< .09

1 estimated average contaminant levels in drinking water during first trimester.

ref = referent group   n.d. = not detected
ppb = parts per billion   ppm = parts per million

2 NS: the two-tail p-value is greater than 0.10.

3 Predominant (> 85%) source of the water supply during the first trimester. ("Mixture of sources" indicates that the water company's supply consisted of at least 15% from each source during the first trimester.)

TABLE 26

Bivariate Odds Ratios. New Jersey Dept. of Health 1985-1988

OUTCOME: NTD - Multiple

CASES = 10 CONTROLS = 52,334

CONTAMINANT LEVELS[1]	# CASES	# CONTROLS	ODDS RATIO	95% CONFIDENCE INTERVAL	2-TAIL P-VALUE[2]
A-280 TOTAL VOLATILE ORGANICS:					
n.d. - 1 ppb (ref)	3	35,968	1.00	---	---
> 1 ppb - 5 ppb	6	9,1322	7.88	1.97 - 31.5	< .005
> 5 ppb - 10 ppb	0	3,091	---	---	---
> 10 ppb	1	4,143	2.89	0.12 - 30.9	NS
> 5 ppb	1	7,234	1.66	0.17 - 15.9	NS
TRICHLOROETHYLENE:					
n.d. - 1 ppb (ref)	7	45,802	1.00	---	---
> 1 ppb - 5 ppb	2	3,790	3.45	0.72 - 16.6	NS
> 5 ppb - 10 ppb	0	1,169	---	---	---
> 10 ppb	1	1.573	4.16	0.19 - 33.3	NS
> 5 ppb	1	2,742	2.39	0.29 - 19.4	NS
TETRACHLOROETHYLENE:					
n.d. - 1 ppb (ref)	7	42,924	1.00	---	---
> 1 ppb - 5 ppb	2	6,032	2.03	0.42 - 9.8	NS
> 5 ppb - 10 ppb	1	2,653	2.31	0.11 - 18.5	NS
> 10 ppb	0	725	---	---	---
> 5 ppb	1	3,378	1.82	0.22 - 14.8	NS
DICHLOROETHYLENES:					
n.d. - 2 ppb (ref)	10	50,829	1.00	---	---
> 2 ppb	0	1,505	---	---	---
n.d. - 1 ppb (ref)	9	48,479	1.00	---	---
> 1 ppb	1	3,855	1.40	0.18 - 11.0	NS
1,1,1-TRICHLOROETHANE:					
n.d. - 2 ppb (ref)	10	49,072	1.00	---	---
> 2 ppb	0	3,262	---	---	---
n.d. - 1 ppb (ref)	5	44,378	1.00	---	---
> 1 ppb	5	7,956	5.58	1.60 - 19.3	< .01

TABLE 26 (continued)
OUTCOME: NTD - Multiple

CONTAMINANT LEVELS[1]	# CASES	# CONTROLS	ODDS RATIO	95% CONFIDENCE INTERVAL	2-TAIL P-VALUE[2]
CARBON TETRACHLORIDE:					
n.d. - 1 ppb (ref)	10	51,977	1.00	---	---
> 1 ppb	0	357	---	---	---
not detected (ref)	9	50,341	1.00	---	---
detected	1	1,993	2.81	0.36 - 22.2	NS
1,2-DICHLOROETHANE:					
n.d. - 1 ppb (ref)	9	51,395	1.00	---	---
> 1 ppb	1	939	6.08	0.77 - 48.1	< .09
not detected (ref)	9	51,262	1.00	---	---
detected	1	1,072	5.31	0.68 - 42.0	NS
BENZENE:					
not detected (ref)	9	50,925	1.00	---	---
detected	1	1,409	4.02	0.51 - 31.7	NS
NITRATES:					
n.d. - 2 ppm (ref)	7	44,872	1.00	---	---
> 2 ppm	3	7,462	2.58	0.67 - 10.0	NS
TOTAL TRIHALOMETHANES:					
n.d.- 20 ppb (ref)	3	19,841	1.00	---	---
> 20 ppb - 40 ppb	2	6,952	1.90	0.32 - 11.4	NS
> 40 ppb - 60 ppb	3	12,727	1.56	0.32 - 7.7	NS
> 60 ppb - 80 ppb	1	9,004	0.73	0.08 - 7.1	NS
> 80 ppb	1	3,810	1.74	0.18 - 16.7	NS
n.d.- 15 ppb (ref)	2	19,015	1.00	---	---
> 15 ppb - 50 ppb	6	15,145	3.77	0.76 - 18.7	NS
> 50 ppb - 75 ppb	0	12,523	---	---	---
> 75 ppb	2	5,651	3.36	0.34 - 33.0	NS
SOURCE OF WATER SUPPLY[3]:					
ground water (ref)	2	17,157	1.00	---	---
surface water	6	29,078	1.77	0.36 - 8.8	NS
mixture of sources	2	6,099	2.81	0.40 - 20.0	NS

1 estimated average contaminant levels in drinking water during first trimester.

ref = referent group   n.d. = not detected
ppb = parts per billion   ppm = parts per million

2 NS: the two-tail p-value is greater than 0.10.

3 Predominant (> 85%) source of the water supply during the first trimester. ("Mixture of sources" indicates that the water company's supply consisted of at least 15% from each source during the first trimester.)

TABLE 27
Bivariate Odds Ratios. New Jersey Dept. of Health 1985-1988
OUTCOME: Oral Clefts

CASES = 83 CONTROLS = 52,334

CONTAMINANT LEVELS[1]	# CASES	# CONTROLS	ODDS RATIO	95% CONFIDENCE INTERVAL	2-TAIL P-VALUE[2]
A-280 TOTAL VOLATILE ORGANICS:					
n.d. - 1 ppb (ref)	53	35,068	1.00	---	---
> 1 ppb - 5 ppb	14	9,132	1.04	0.58 - 1.9	NS
> 5 ppb - 10 ppb	6	3,091	1.32	0.57 - 3.1	NS
> 10 ppb	10	4,143	1.64	0.83 - 3.2	NS
> 5 ppb	16	7,234	1.50	0.86 - 2.6	NS
TRICHLOROETHYLENE:					
n.d. - 1 ppb (ref)	67	45,802	1.00	---	---
> 1 ppb - 5 ppb	7	3,790	1.26	0.58 - 2.8	NS
> 5 ppb - 10 ppb	6	1,169	3.51	1.52 - 8.1	< .005
> 10 ppb	3	1,573	1.30	0.41 - 4.2	NS
> 5 ppb	9	2,742	2.24	1.12 - 4.5	< .025
TETRACHLOROETHYLENE:					
n.d. - 1 ppb (ref)	67	42,924	1.00	---	---
> 1 ppb - 5 ppb	11	6,032	1.17	0.62 - 2.2	NS
> 5 ppb - 10 ppb	1	2,653	0.24	0.03 - 1.7	NS
> 10 ppb	4	725	3.54	1.29 - 9.7	< .015
> 5 ppb	5	3,378	0.95	0.38 - 2.4	NS
DICHLOROETHYLENES:					
n.d. - 2 ppb (ref)	79	50,829	1.00	---	---
> 2 ppb	4	1,505	1.71	0.63 - 4.7	NS
n.d. - 1 ppb (ref)	77	48,479	1.00	---	---
> 1 ppb	6	3,855	0.98	0.43 - 2.3	NS
1,1,1-TRICHLOROETHANE:					
n.d. - 2 ppb (ref)	76	49,072	1.00	---	---
> 2 ppb	7	3,262	1.39	0.64 - 3.0	NS
n.d. - 1 ppb (ref)	70	44,378	1.00	---	---
> 1 ppb	13	7,956	1.04	0.57 - 1.9	NS

TABLE 27 (continued)
OUTCOME: Oral Clefts

CONTAMINANT LEVELS[1]	# CASES	# CONTROLS	ODDS RATIO	95% CONFIDENCE INTERVAL	2-TAIL P-VALUE[2]
CARBON TETRACHLORIDE:					
n.d. - 1 ppb (ref)	81	51,977	1.00	---	---
> 1 ppb	2	357	3.60	0.88 - 14.7	< .08
not detected (ref)	78	50,341	1.00	---	---
detected	5	1,993	1.62	0.66 - 4.0	NS
1,2-DICHLOROETHANE:					
n.d. - 1 ppb (ref)	82	51,395	1.00	---	---
> 1 ppb	1	939	0.67	0.09 - 4.8	NS
not detected (ref)	82	51,262	1.00	---	---
detected	1	1,072	0.58	0.08 - 4.2	NS
BENZENE:					
not detected (ref)	82	50,925	1.00	---	---
detected	1	1,409	0.44	0.06 - 3.2	NS
NITRATES:					
n.d. - 2 ppm (ref)	68	44,872	1.00	---	---
> 2 ppm	15	7,462	1.33	0.76 - 2.3	NS
TOTAL TRIHALOMETHANES:					
n.d.- 20 ppb (ref)	33	19,841	1.00	---	---
> 20 ppb - 40 ppb	12	6,952	1.04	0.54.- 2.0	NS
> 40 ppb - 60 ppb	14	12,727	0.66	0.35 - 1.2	NS
> 60 ppb - 80 ppb	13	9,004	0.87	0.46 - 1.7	NS
> 80 ppb	11	3,810	1.74	0.88 - 3.4	NS
n.d.- 15 ppb (ref)	32	19,015	1.00	---	---
> 15 ppb - 50 ppb	20	15,145	0.78	0.45 - 1.4	NS
> 50 ppb - 75 ppb	18	12,523	0.85	0.48 - 1.5	NS
> 75 ppb	13	5,651	1.37	0.72 - 2.6	NS
SOURCE OF WATER SUPPLY[3]:					
ground water (ref)	28	17,157	1.00	---	---
surface water	47	29,078	0.99	0.62 - 1.6	NS
mixture of sources	8	6,099	0.80	0.37 - 1.8	NS

1 estimated average contaminant levels in drinking water during first trimester.

ref = referent group n.d. = not detected
ppb = parts per billion ppm = parts per million

2 NS: the two-tail p-value is greater than 0.10.

3 Predominant (> 85%) source of the water supply during the first trimester. ("Mixture of sources" indicates that the water company's supply consisted of at least 15% from each source during the first trimester.)

TABLE 28

Bivariate Odds Ratios. New Jersey Dept. of Health 1985-1988

OUTCOME: Cleft Lip (with or without Cleft Palate)

CASES = 53 CONTROLS = 52,334

CONTAMINANT LEVELS[1]	# CASES	# CONTROLS	ODDS RATIO	95% CONFIDENCE INTERVAL	2-TAIL P-VALUE[2]
A-280 TOTAL VOLATILE ORGANICS:					
n.d. - 1 ppb (ref)	34	35,968	1.00	---	---
> 1 ppb - 5 ppb	7	9,132	0.81	0.36 - 1.8	NS
> 5 ppb - 10 ppb	6	3,091	2.05	0.86 - 4.9	NS
> 10 ppb	6	4,143	1.53	0.64 - 3.7	NS
> 5 ppb	12	7,234	1.76	0.91 - 3.4	< .095
TRICHLOROETHYLENE:					
n.d. - 1 ppb (ref)	45	45,802	1.00	---	---
> 1 ppb - 5 ppb	3	3,790	0.81	0.25 - 2.6	NS
> 5 ppb - 10 ppb	3	1,169	2.61	0.81 - 8.4	NS
> 10 ppb	2	1,573	1.29	0.31 - 5.3	NS
> 5 ppb	5	2,742	1.86	0.74 - 4.7	NS
TETRACHLOROETHYLENE:					
n.d. - 1 ppb (ref)	41	42,924	1.00	---	---
> 1 ppb - 5 ppb	8	6,032	1.39	0.65 - 3.0	NS
> 5 ppb - 10 ppb	1	2,653	0.49	0.05 - 2.9	NS
> 10 ppb	3	725	4.33	1.34 - 14	< .015
> 5 ppb	4	3,378	1.24	0.44 - 3.5	NS
DICHLOROETHYLENES:					
n.d. - 2 ppb (ref)	51	50,829	1.00	---	---
> 2 ppb	2	1,505	1.32	0.32 - 5.4	NS
n.d. - 1 ppb (ref)	50	48,479	1.00	---	---
> 1 ppb	3	3,855	0.75	0.24 - 2.4	NS
1,1,1-TRICHLOROETHANE:					
n.d. - 2 ppb (ref)	48	49,072	1.00	---	---
> 2 ppb	5	3,626	1.57	0.62 - 3.9	NS
n.d. - 1 ppb (ref)	45	44,378	1.00	---	---
> 1 ppb	8	7,956	0.99	0.47 - 2.1	NS

TABLE 28 (continued)

OUTCOME: Cleft Lip (with or without Cleft Palate)

CONTAMINANT LEVELS[1]	# CASES	# CONTROLS	ODDS RATIO	95% CONFIDENCE INTERVAL	2-TAIL P-VALUE[2]
CARBON TETRACHLORIDE:					
n.d. - 1 ppb (ref)	52	51,977	1.00	---	---
> 1 ppb	1	357	2.8	0.39- 20.3	NS
not detected (ref)	50	50,341	1.00	---	---
detected	3	1,993	1.52	0.47 - 4.9	NS
1,2-DICHLOROETHANE:					
n.d. - 1 ppb (ref)	52	51,395	1.00	---	---
> 1 ppb	1	939	1.05	0.15 - 7.6	NS
not detected (ref)	52	51,262	1.00	---	---
detected	1	1,072	0.92	0.13 - 6.7	NS
BENZENE:					
not detected (ref)	52	50,925	1.00	---	---
detected	1	1,409	0.70	0.10 - 5	NS
NITRATES:					
n.d. - 2 ppm (ref)	43	44,872	1.00	---	---
> 2 ppm	10	7,462	1.4	0.7 - 2.8	NS
TOTAL TRIHALOMETHANES:					
n.d.- 20 ppb (ref)	24	19,841	1.00	---	---
> 20 ppb - 40 ppb	6	6,952	0.71	0.29 - 1.7	NS
> 40 ppb - 60 ppb	9	12,727	0.58	0.27 - 1.3	NS
> 60 ppb - 80 ppb	7	9,004	0.64	0.28 - 1.5	NS
> 80 ppb	7	3,810	1.52	0.65 - 3.5	NS
n.d.- 15 ppb (ref)	23	19,015	1.00	---	---
> 15 ppb - 50 ppb	11	15,145	0.60	0.29 - 1.2	NS
> 50 ppb - 75 ppb	11	12,523	0.73	0.35 - 1.5	NS
> 75 ppb	8	5,651	1.17	0.52 - 2.6	NS
SOURCE OF WATER SUPPLY[3]:					
ground water (ref)	20	17,157	1.00	---	---
surface water	27	29,078	0.80	0.45 - 1.4	NS
mixture of sources	6	6,099	0.84	0.34 - 2.1	NS

1 estimated average contaminant levels in drinking water during first trimester.

ref = referent group n.d. = not detected
ppb = parts per billion ppm = parts per million

2 NS: the two-tail p-value is greater than 0.10.

3 Predominant (> 85%) source of the water supply during the first trimester. ("Mixture of sources" indicates that the water company's supply consisted of at least 15% from each source during the first trimester.)

TABLE 29

Bivariate Odds Ratios. New Jersey Dept. of Health 1985-1988

OUTCOME: Cleft Palate

CASES = 30 CONTROLS = 52,334

CONTAMINANT LEVELS[1]	# CASES	# CONTROLS	ODDS RATIO	95% CONFIDENCE INTERVAL	2-TAIL P-VALUE[2]
A-280 TOTAL VOLATILE ORGANICS:					
n.d. - 1 ppb (ref)	19	35,968	1.00	---	---
> 1 ppb - 5 ppb	7	9,132	1.45	0.61 - 3.5	NS
> 5 ppb - 10 ppb	0	3,091	---	---	---
> 10 ppb	4	4,143	1.83	0.53 - 5.7	NS
> 5 ppb	4	7,234	1.05	0.36 - 3.1	NS
TRICHLOROETHYLENE:					
n.d. - 1 ppb (ref)	22	45,802	1.00	---	---
> 1 ppb - 5 ppb	4	3,790	2.20	0.76 - 6.4	NS
> 5 ppb - 10 ppb	3	1,169	5.34	1.6 - 17.9	< .01
> 10 ppb	1	1,573	1.32	0.18 - 9.8	NS
> 5 ppb	4	2,742	3.04	1.05 - 8.8	< .045
TETRACHLOROETHYLENE:					
n.d. - 1 ppb (ref)	26	42,924	1.00	---	---
> 1 ppb - 5 ppb	3	6,032	0.82	0.25 - 2.7	NS
> 5 ppb - 10 ppb	0	2,653	---	---	---
> 10 ppb	1	725	2.28	0.11 - 15.7	NS
> 5 ppb	1	3,378	0.49	0.07 - 3.6	NS
DICHLOROETHYLENES:					
n.d. - 2 ppb (ref)	28	50,829	1.00	---	---
> 2 ppb	2	1,505	2.41	0.57 - 10.1	NS
n.d. - 1 ppb (ref)	27	48,479	1.00	---	---
> 1 ppb	3	3,855	1.40	0.42 - 4.6	NS
1,1,1-TRICHLOROETHANE:					
n.d. - 2 ppb (ref)	28	49,072	1.00	---	---
> 2 ppb	2	3,262	1.08	0.26 - 4.5	NS
n.d. - 1 ppb (ref)	25	44,378	1.00	---	---
> 1 ppb	5	7,956	1.12	0.43 - 2.9	NS

TABLE 29 (continued)
OUTCOME: Cleft Palate

CONTAMINANT LEVELS[1]	# CASES	# CONTROLS	ODDS RATIO	95% CONFIDENCE INTERVAL	2-TAIL P-VALUE[2]
CARBON TETRACHLORIDE:					
n.d. - 1 ppb (ref)	29	51,977	1.00	---	---
> 1 ppb	1	357	5.02	0.68 - 37.0	NS
not detected (ref)	28	50,341	1.00	---	---
detected	2	1,993	1.80	0.43 - 7.6	NS
1,2-DICHLOROETHANE:					
n.d. - 1 ppb (ref)	30	51,395	1.00	---	---
> 1 ppb	0	939	---	---	---
not detected (ref)	30	51,262	1.00	---	---
detected	0	1,072	---	---	---
BENZENE:					
not detected (ref)	30	50,925	1.00	---	---
detected	0	1,409	---	----	---
NITRATES:					
n.d. - 2 ppm (ref)	25	44,872	1.00	---	---
> 2 ppm	5	7,462	1.20	0.46 - 3.1	---
TOTAL TRIHALOMETHANES:					
n.d.- 20 ppb (ref)	9	19,841	1.00	---	---
> 20 ppb - 40 ppb	6	6,952	1.90	0.68 - 5.3	NS
> 40 ppb - 60 ppb	5	12,727	0.87	0.29 - 2.6	NS
> 60 ppb - 80 ppb	6	9,004	1.47	0.52 - 4.1	NS
> 80 ppb	4	3,810	2.31	0.71 - 7.5	NS
n.d.- 15 ppb (ref)	9	19,015	1.00	---	
> 15 ppb - 50 ppb	9	15,145	1.26	0.50 - 3.2	NS
> 50 ppb - 75 ppb	7	12,523	1.18	0.44 - 3.2	NS
> 75 ppb	5	5,651	1.87	0.63 - 5.6	NS
SOURCE OF WATER SUPPLY[3]:					
ground water (ref)	8	17,157	1.00	---	---
surface water	20	29,078	1.48	0.65 - 3.4	NS
mixture of sources	2	6,099	0.70	0.15 - 3.3	NS

1 estimated average contaminant levels in drinking water during first trimester.

ref = referent group n.d. = not detected
ppb = parts per billion ppm = parts per million

2 NS: the two-tail p-value is greater than 0.10.

3 Predominant (> 85%) source of the water supply during the first trimester. ("Mixture of sources" indicates that the water company's supply consisted of at least 15% from each source during the first trimester.)

TABLE 30

Bivariate Odds Ratios. New Jersey Dept. of Health 1985-1988

OUTCOME: Major Cardiac Defects

CASES = 108 CONTROLS = 52,334

CONTAMINANT LEVELS[1]	# CASES	# CONTROLS	ODDS RATIO	95% CONFIDENCE INTERVAL	2-TAIL P-VALUE[2]
A-280 TOTAL VOLATILE ORGANICS:					
n.d. - 1 ppb (ref)	71	35,968	1.00	---	---
> 1 ppb - 5 ppb	26	9,1322	1.44	0.92 - 2.3	NS
> 5 ppb - 10 ppb	4	3,091	0.66	0.24 - 1.8	NS
> 10 ppb	7	4,143	0.86	0.40 - 1.9	NS
> 5 ppb	11	7,234	0.77	0.41 - 1.5	NS
TRICHLOROETHYLENE:					
n.d. - 1 ppb (ref)	94	45,802	1.00	---	---
> 1 ppb - 5 ppb	8	3,790	1.03	0.50 - 2.1	NS
> 5 ppb - 10 ppb	2	1,169	0.83	0.21 - 3.4	NS
> 10 ppb	4	1,573	1.24	0.46 - 3.4	
> 5 ppb	6	2,742	1.07	0.47 - 2.4	NS
TETRACHLOROETHYLENE:					
n.d. - 1 ppb (ref)	90	42,924	1.00	---	---
> 1 ppb - 5 ppb	10	6,032	0.79	0.41 - 1.5	NS
> 5 ppb - 10 ppb	7	2,653	1.26	0.58 - 2.7	NS
> 10 ppb	1	725	0.66	0.09 - 4.7	NS
> 5 ppb	8	3,378	1.13	0.55 - 2.3	NS
DICHLOROETHYLENES:					
n.d. - 2 ppb (ref)	106	50,829	1.00	---	---
> 2 ppb	2	1,505	0.64	0.16 - 2.6	NS
n.d. - 1 ppb (ref)	101	48,479	1.00	---	---
> 1 ppb	7	3,855	0.87	0.40 - 1.9	NS
1,1,1-TRICHLOROETHANE:					
n.d. - 2 ppb (ref)	107	49,072	1.00	---	---
> 2 ppb	1	3,262	0.14	0.02 - 1.01	< .055
n.d. - 1 ppb (ref)	92	44,378	1.00	---	---
> 1 ppb	16	7,956	0.97	0.57 - 1.7	NS

TABLE 30 (continued)
OUTCOME: Major Cardiac Defects

CONTAMINANT LEVELS[1]	# CASES	# CONTROLS	ODDS RATIO	95% CONFIDENCE INTERVAL	2-TAIL P-VALUE[2]
CARBON TETRACHLORIDE:					
n.d. - 1 ppb (ref)	108	51,977	1.00	---	---
> 1 ppb	0	357	---	---	---
not detected (ref)	104	50,341	1.00	---	---
detected	4	1,993	0.97	0.36 - 2.6	NS
1,2-DICHLOROETHANE:					
n.d. - 1 ppb (ref)	104	51,395	1.00	---	---
> 1 ppb	4	939	2.11	0.77 - 5.7	NS
not detected (ref)	102	51,262	1.00	---	---
detected	6	1,072	2.81	1.23 - 6.4	< .015
BENZENE:					
not detected (ref)	103	50,925	1.00	---	---
detected	5	1,409	1.75	0.71 - 4.3	NS
NITRATES:					
n.d. - 2 ppm (ref)	95	44,872	1.00	---	---
> 2 ppm	13	7,462	0.82	0.46 - 1.5	NS
TOTAL TRIHALOMETHANES:					
n.d.- 20 ppb (ref)	34	19,841	1.00	---	---
> 20 ppb - 40 ppb	16	6,952	1.34	0.74 - 2.4	NS
> 40 ppb - 60 ppb	33	12,727	1.51	0.94 - 2.4	< .095
> 60 ppb - 80 ppb	13	9,004	0.84	0.44 - 1.6	NS
> 80 ppb	12	3,810	1.84	0.95 - 3.6	< .075
n.d.- 15 ppb (ref)	30	19,015	1.00	---	---
> 15 ppb - 50 ppb	40	15,145	1.67	1.04 - 2.7	< .035
> 50 ppb - 75 ppb	23	12,523	1.16	0.68 - 2.0	NS
> 75 ppb	15	5,651	1.68	0.91 - 3.1	NS
SOURCE OF WATER SUPPLY[3]:					
ground water (ref)	26	17,157	1.00	---	---
surface water	68	29,078	1.54	0 98 - 2.4	< .065
mixture of sources	14	6,099	1.51	7.9 - 2.9	NS

1 estimated average contaminant levels in drinking water during first trimester.

ref = referent group — n.d. = not detected
ppb = parts per billion — ppm = parts per million

2 NS: the two-tail p-value is greater than 0.10.

3 Predominant (> 85%) source of the water supply during the first trimester. ("Mixture of sources" indicates that the water company's supply consisted of at least 15% from each source during the first trimester.)

TABLE 31

Bivariate Odds Ratios. New Jersey Dept. of Health 1985-1988

OUTCOME: Ventricular Septal Defect (VSD)

CASES = 109 CONTROLS = 52,334

CONTAMINANT LEVELS[1]	# CASES	# CONTROLS	ODDS RATIO	95% CONFIDENCE INTERVAL	2-TAIL P-VALUE[2]
A-280 TOTAL VOLATILE ORGANICS:					
n.d. - 1 ppb (ref)	72	35,968	1.00	---	---
> 1 ppb - 5 ppb	19	9,132	1.04	0.63 - 1.7	NS
> 5 ppb - 10 ppb	8	3,091	1.29	0.62 - 2.7	NS
> 10 ppb	10	4,143	1.21	0.62 - 2.3	NS
> 5 ppb	18	7,234	1.24	0.74 - 2.1	NS
TRICHLOROETHYLENE:					
n.d. - 1 ppb (ref)	95	45,802	1.00	---	---
> 1 ppb - 5 ppb	5	3,790	0.64	0.26 - 1.6	NS
> 5 ppb - 10 ppb	5	1,169	2.06	0.84 - 5.1	NS
> 10 ppb	4	1,573	1.23	0.45 - 3.3	NS
> 5 ppb	9	2,742	1.58	0.80 - 3.1	NS
TETRACHLOROETHYLENE:					
n.d. - 1 ppb (ref)	87	42,924	1.00	---	---
> 1 ppb - 5 ppb	14	6,032	1.15	0.65 - 2.0	NS
> 5 ppb - 10 ppb	8	2,653	1.49	0.67 - 3.2	NS
> 10 ppb	0	725	---	---	---
> 5 ppb	8	3,378	1.17	0.57 - 2.4	NS
DICHLOROETHYLENES:					
n.d. - 2 ppb (ref)	106	50,829	1.00	---	---
> 2 ppb	3	1,505	0.96	0.30 - 3.0	NS
n.d. - 1 ppb (ref)	101	48,479	1.00	---	---
> 1 ppb	8	3,855	1.0	0.49 - 2.1	NS
1,1,1-TRICHLOROETHANE:					
n.d. - 2 ppb (ref)	105	49,072	1.00	---	---
> 2 ppb	4	3,262	0.57	0.21 - 1.6	NS
n.d. - 1 ppb (ref)	93	44,378	1.00	---	---
> 1 ppb	16	7,956	0.96	0.56 - 1.6	NS

TABLE 31 (continued)
OUTCOME: Ventricular Septal Defect (VSD)

CONTAMINANT LEVELS[1]	# CASES	# CONTROLS	ODDS RATIO	95% CONFIDENCE INTERVAL	2-TAIL P-VALUE[2]
CARBON TETRACHLORIDE:					
n.d. - 1 ppb (ref)	108	51,977	1.00	---	---
> 1 ppb	1	357	1.35	0.21 - 1.6	NS
not detected (ref)	106	50,341	1.00	---	---
detected	3	1,993	0.72	0.56 - 1.6	NS
1,2-DICHLOROETHANE:					
n.d. - 1 ppb (ref)	106	51,395	1.00	---	---
> 1 ppb	3	939	1.55	0.49 - 4.9	NS
not detected (ref)	105	51,262	1.00	---	---
detected	4	1,072	1.82	0.67 - 5.0	NS
BENZENE:					
not detected (ref)	105	50,925	1.00	---	---
detected	4	1,409	1.38	0.51 - 3.7	NS
NITRATES:					
n.d. - 2 ppm (ref)	95	44,872	1.00	---	---
> 2 ppm	14	7,462	0.89	0.51 - 1.6	NS
TOTAL TRIHALOMETHANES:					
n.d.- 20 ppb (ref)	38	19,841	1.00	---	---
> 20 ppb - 40 ppb	13	6,952	0.98	0.52 - 1.8	NS
> 40 ppb - 60 ppb	33	12,727	1.35	0.85 - 1.1	NS
> 60 ppb - 80 ppb	15	9,004	0.87	0.48 - 1.6	NS
> 80 ppb	10	3,810	1.37	0.68 - 2.8	NS
n.d.- 15 ppb (ref)	36	19,015	1.00	---	---
> 15 ppb - 50 ppb	35	15,145	1.22	0.77 - 1.9	NS
> 50 ppb - 75 ppb	26	12,523	1.10	0.66 - 1.8	NS
> 75 ppb	12	5,651	1.12	0.58 - 2.2	NS
SOURCE OF WATER SUPPLY[3]:					
ground water (ref)	33	17,157	1.00	---	---
surface water	64	29,078	1.14	0.75 - 1.7	NS
mixture of sources	12	6,099	1.02	0.53 - 2.0	NS

1 estimated average contaminant levels in drinking water during first trimester.

ref = referent group   n.d. = not detected
ppb = parts per billion   ppm = parts per million

2 NS: the two-tail p-value is greater than 0.10.

3 Predominant (> 85%) source of the water supply during the first trimester. ("Mixture of sources" indicates that the water company's supply consisted of at least 15% from each source during the first trimester.)

TABLE 32

Bivariate Odds Ratios. New Jersey Dept. of Health 1985-1988

OUTCOME: All Cardiac Defects

CASES = 346 CONTROLS = 52,334

CONTAMINANT LEVELS[1]	# CASES	# CONTROLS	ODDS RATIO	95% CONFIDENCE INTERVAL	2-TAIL P-VALUE[2]
A-280 TOTAL VOLATILE ORGANICS:					
n.d. - 1 ppb (ref)	239	35,968	1.00	---	---
> 1 ppb - 5 ppb	76	9,1322	1.25	0.97 - 1.6	< .09
> 5 ppb - 10 ppb	13	3,091	0.63	0.36 - 1.1	NS
> 10 ppb	18	4,143	0.65	0.40 - 1.1	< .09
> 5 ppb	31	7,234	0.64	0.44 - 0.94	< .025
TRICHLOROETHYLENE:					
n.d. - 1 ppb (ref)	316	45,802	1.00	---	---
> 1 ppb - 5 ppb	13	3,790	0.50	0.29 - 0.87	< .015
> 5 ppb - 10 ppb	10	1,169	1.24	0.66 - 2.3	NS
> 10 ppb	7	1,573	0.65	0.30 - 1.4	NS
> 5 ppb	17	2,742	0.90	0.55 - 1.5	NS
TETRACHLOROETHYLENE:					
n.d. - 1 ppb (ref)	297	42,924	1.00	---	---
> 1 ppb - 5 ppb	34	6,032	0.82	0.57 - 1.2	NS
> 5 ppb - 10 ppb	14	2,653	0.76	0.45 - 1.3	NS
> 10 ppb	1	725	0.20	0.03 - 1.4	NS
> 5 ppb	15	3,378	0.64	0.38 - 1.1	< .10
DICHLOROETHYLENES:					
n.d. - 2 ppb (ref)	339	50,829	1.00	---	---
> 2 ppb	7	1,505	0.70	0.33 - 1.5	NS
n.d. - 1 ppb (ref)	331	48,479	1.00	---	---
> 1 ppb	15	3,855	0.57	0.34 - 0.96	< .035
1,1,1-TRICHLOROETHANE:					
n.d. - 2 ppb (ref)	336	49,072	1.00	---	---
> 2 ppb	10	3,262	0.45	0.24 - 0.84	< .015
n.d. - 1 ppb (ref)	297	44,378	1.00	---	---
> 1 ppb	49	7,956	0.92	0.68 - 1.25	NS

TABLE 32 (continued)
OUTCOME: <u>All Cardiac Defects</u>

CONTAMINANT LEVELS[1]	# CASES	# CONTROLS	ODDS RATIO	95% CONFIDENCE INTERVAL	2-TAIL P-VALUE[2]
CARBON TETRACHLORIDE:					
n.d. - 1 ppb (ref)	345	51,977	1.00	---	---
> 1 ppb	1	357	0.42	0.06 - 3.0	NS
not detected (ref)	338	50,341	1.00	---	---
detected	8	1,993	0.60	0.30 - 1.2	NS
1,2-DICHLOROETHANE:					
n.d. - 1 ppb (ref)	340	51,395	1.00	---	---
> 1 ppb	6	939	0.97	0.43 - 2.2	NS
not detected (ref)	338	51,262	1.00	---	---
detected	8	1,072	1.13	0.56 - 2.3	NS
BENZENE:					
not detected (ref)	338	50,925	1.00	---	---
detected	8	1,409	0.86	0.42 - 1.7	NS
NITRATES:					
n.d. - 2 ppm (ref)	313	44,872	1.00	---	---
> 2 ppm	33	7,462	0.63	0.44 - 0.91	< .015
TOTAL TRIHALOMETHANES:					
n.d.- 20 ppb (ref)	112	19,841	1.00	---	---
> 20 ppb - 40 ppb	39	6,952	0.99	0.69 - 1.4	NS
> 40 ppb - 60 ppb	105	12,727	1.46	1.12 - 1.9	< .01
> 60 ppb - 80 ppb	59	9,004	1.16	0.85 - 1.6	NS
> 80 ppb	31	3,810	1,44	0.97 - 2.1	< .075
n.d.- 15 ppb (ref)	105	19,015	1.00	---	---
> 15 ppb - 50 ppb	110	15,145	1.32	1.01 - 1.7	< .05
> 50 ppb - 75 ppb	92	12,523	1.33	1.01 - 1.8	< .05
> 75 ppb	39	5,651	1.25	0.86 - 1.8	NS
SOURCE OF WATER SUPPLY[3]:					
ground water (ref)	94	17,157	1.00	---	---
surface water	224	29,078	1.41	1.10 - 1.8	< .01
mixture of sources	28	6,099	0.84	0.55 - 1.3	NS

1 estimated average contaminant levels in drinking water during first trimester.

ref = referent group n.d. = not detected
ppb = parts per billion ppm = parts per million

2 NS: the two-tail p-value is greater than 0.10.

3 Predominant (> 85%) source of the water supply during the first trimester. ("Mixture of sources" indicates that the water company's supply consisted of at least 15% from each source during the first trimester.)

TABLE 33

POSITIVE ASSOCIATIONS SUGGESTING FOLLOW-UP RESEARCH
NEW JERSEY DEPARTMENT OF HEALTH 1985-1988

A. "A-280" CONTAMINANTS[1]
ODDS RATIOS AND BIRTHWEIGHT DEFICITS

OUTCOME[1]	TVOC	TCE	PCE	DCE	CTC	EDC
Exposure	>10 ppb	>10 ppb	>10 ppb	>2 ppb	>1 ppb	detected
Low birth-weight among term births					2.26	
SGA					1.35	
Prematurity						
Very low birthweight						
Stillbirths						
Surveillance birth defects						
CNS defects				2.52	4.64	
NTDs	5.13m	2.53s		2.60s	5.39	
Oral clefts	1.76[Ls]	2.24	3.54		3.60[s]	
All cardiacs						
Major cardiacs						2.81
Ventricular septal defects						

See text regarding whether OR is for adjusted or unadjusted analysis.

1 There were no positive associations for TCA or benzene and no significant deficits for "A280" chemicals for birthweight as a continuous variable.

s Association was <u>less precise</u>, i.e., the 95% confidence interval included the null hypothesis value (OR=1.0) and the two-tail p value was > 0.05 and < 0.10.

m The association was for <u>multiple</u> NTD defects only.

L The association was only for cleft <u>lip</u> (with or without cleft palate).

TABLE 33 Continued

B. OTHER DRINKING WATER CONTAMINANTS
ODDS RATIOS AND BIRTHWEIGHT DEFICITS

NEW JERSEY DEPARTMENT OF HEALTH 1985-1988

OUTCOME[2]	NITRATES	TTHM	SURFACE WATER	MIXED SOURCE
Exposure	>2 ppm	>80 ppb		
Birthweight among term births		37 g deficit (70 g deficit at MCL of 100 ppb)	31 g deficit	
Low birth-weight among term births		1.34	1.35	1.17[s]
SGA		1.22	1.22	
Prematurity		1.09[s]	1.12	1.08[s]
Very low birthweight			1.17	
Stillbirths			1.37	
Surveillance birth defects		1.58	1.31	
CNS defects	1.77T	2.60		
NTDs	2.37T	2.98		2.34s
Oral Clefts				
All cardiacs		1.44[s]	1.41	
Major cardiacs		1.84[s]	1.54[s]	
Ventricular septal defects				

s Association was less precise i.e., the 95% confidence interval included the null hypothesis value (e.g., OR=1.0) and the two-tail p-value was between 0.05 and 0.10.

g grams

T TTHM included in model

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PHASE IVA: PUBLIC DRINKING WATER CONTAMINATION

AND BIRTHWEIGHT, FETAL DEATHS, AND BIRTH DEFECTS

A CROSS-SECTIONAL STUDY

APPENDIX

1. INTRODUCTION

The water company databases used in this study were obtained from NJDEP in hard copy form. A computerized version of the A-280 database was also obtained but did not prove to be useful as is. For example, there were two different databases - one for "positive" findings (i.e., detected contamination, although there were a few "negative" findings included for no apparent reason) and another for both "negative" and "positive" findings (although this did not include all the negative or positive findings). The first database was in DBASE format, the second was in SAS format. Neither database was complete and both had numerous data errors (e.g., misplaced decimal points and miscoding of chemicals detected). The hard copies of the drinking water databases also contained numerous data errors, chief among them being misplaced decimal points.

It must be remembered that these databases served primarily administrative and regulatory purposes and were not immediately appropriate for exposure assessment purposes. Substantial work was required to prepare the data for use in the exposure assessment process. In addition, a considerable degree of interpretation, judgment and external information (e.g., directly from the water companies or from NJDEP staff) was necessary to make the data useful for this project.

2. THE NJDEP "A-280" DATABASE

Data on the levels of volatile organics (other than trihalomethanes) in public drinking water supplies were obtained from the BSDW's "A-280" Program.

The database included information on the date of the sample and whether the sample was from the distribution system (i.e., a tap sample), a "plant-delivered" sample (i.e., a sample at the point where a particular well's supply enters the distribution system) or a "raw water" sample (i.e., a sample prior to treatment and therefore not reflective of drinking water quality). Most of the time, the location of the sample was also provided.

The A-280 Program required all public water companies to sample their distribution systems at least twice annually and to submit these samples to NJDEP-certified laboratories for analysis of 14 volatile organics (TCE, PCE, TCA, CTC, EDC, benzene, trans-1,2-dichloroethylene, 1,1-dichloroethylene, methylene chloride, xylenes, vinyl chloride, trichlorobenzenes, 1,4-dichlorobenzene, chlorobenzene), PCBs and chlordane.

The method detection limit or "MDL (i.e., the lowest concentration level to which a contaminant can be measured by an analytical method with confidence that the level is greater than zero) was less than 1 part per billion (ppb) for all A-280 contaminants except vinyl chloride (about 1.1 ppb). However, the MDL is not considered by EPA to be the best measure of the capability of analytical methods. Another measure used by EPA is the "practical quantitation level" or "PQL" which is the level where quantitation can be achieved with "acceptable" uncertainty among most laboratories. This is usually between three and ten times the MDL and is based on the average percent difference of the lab mean from the true value, the within-lab variability and the between-lab variability.

For TCE, PCE, TCA and benzene, the NJ Drinking Water Quality Institute (an interagency group) set the PQL at 1 ppb. For vinyl chloride, the PQL was set at 5ppb and for carbon tetrachloride, 2 ppb. The dichloroethylenes and 1,2-dichloroethane (EDC) were not studied but were given a PQL of 2 ppb.

Samples representing the distribution system for each company serving the 75 towns in the study for the period 1985-88 were used to characterize total VOC (TVOC) and individual VOC levels in each town's system on a monthly basis. The number of samples varied considerably by company. At a minimum, two samples annually (three samples in 1985) were required. However, if contamination was detected, additional sampling was required.

3. THE NJDEP TRIHALOMETHANE DATABASE

NJDEP's database on total trihalomethane (TTHM) levels in the distribution system of each company serving at least 1,000 people was obtained for the period 1984-1988. Samples were required on a quarterly basis by NJDEP since TTHM levels varied by season.

A few of the large companies that served several towns in the study area utilized both groundwater and surface water sources; therefore, in order to estimate exposures to each town, additional information was needed on the mix of water (i.e., % groundwater and % surface water) that was supplied to each town. A simple average of all the samples taken on the quarterly sampling date was not appropriate in these cases. Instead, a judgment had to be made by the researcher as to which samples taken on the quarterly sampling date reflected the surface water, the groundwater or a mixture of sources. Once the sample(s) for each source (and mixture) were identified, "source-specific" averages were calculated.

The method detection limit for TTHM was 1 ppb. A sample that was reported as "< 1 ppb" was given the value of 1 ppb when calculating the mean. Levels of individual contaminants that make up the TTHM (e.g., chloroform) were not available on hard copy until 1988 and were therefore not evaluated in the study. Generally, the major component of TTHM was chloroform.

The locations of the TTHM samples were not available. It was assumed that the water companies, as required by EPA and NJDEP, performed the sampling at the furthest reaches of their distribution systems in order to obtain the highest readings of TTHMs. (The level of TTHM in the drinking water increases with increasing distance from the point of chlorination treatment since the reactions producing TTHM have more time to take place.)

4. THE NJDEP INORGANICS DATABASE

BSDW supplied data on nitrate levels for the water companies in the study area. The dates of the samples were provided but not their locations. Other inorganic contaminants were not evaluated since none of their US Maximum Contamination Levels (MCLs) were exceeded in the study area and since most of the data merely indicated that levels were below the MCLs without supplying the actual levels detected. Although the MCL for nitrates was never exceeded in the study area, the actual levels detected were given in the database.

Some water companies, especially the larger systems, sampled on an annual basis. However, for more than 75% of the companies in the study, sample data were recorded less than annually during the study period. Often only two sampling dates (i.e., two annual samples) were recorded over the 5-year study period.

5. METHODS

For each town, a form was filled out which included the names of the water companies serving the town, the number of services (meters) of each water company in the town, the percent of the town's total supply provided by each company and the source of water supply for each company serving the town (i.e., % groundwater and % surface water). In addition, the hard copy data on A-280, TTHM and nitrate contaminants were abstracted onto worksheets attached to the form. All distribution and "plant delivered" A-280 samples, the dates the samples were taken and the levels of the contaminants found were recorded on the worksheets. The locations of the samples were recorded for the A-280 samples (if available on hard copy). The TTHM samples for each sampling date were averaged.

The forms and worksheets were sent to BSDW staff for comment. BSDW staff provided additional information on the water systems of the companies and corrected obvious data errors (e.g., misplaced decimal points) that were found in the hard copy database. For some companies, there was a question of whether the samples in the hard copy database were correctly defined as distribution samples or whether they were "raw water" samples. BSDW staff attempted to obtain information directly from the water companies to resolve these questions. Once the forms and worksheets were returned, the initial monthly estimates of drinking water exposures for each town were determined.

Almost all the towns had only one supplier. A few towns had additional suppliers but they contributed a tiny amount of the town's total supply (< 4%) and were ignored. Two towns had both a major (> 50%) and a minor (< 50%) supplier. Some companies served more than one town. Data from a total of 49 water companies were used to estimate monthly drinking water exposures in the 75 towns.

In order to estimate monthly exposures to A-280 contaminants, extrapolation from each sampling date was necessary (see Section 2.4 for a description of the extrapolation algorithm). For each water company, the initial sample (taken in late 1984 or early 1985) was used to estimate monthly concentrations during 1984. However, for a few companies, the initial sample was not used to characterize 1984 since either data were available from remedial investigation work during 1984 (e.g., Lodi and Rockaway Boro) or information from BSDW staffers indicated that the initial sample was not reflective of previous contamination levels. In the latter case, samples taken during the first half of 1985 (or the entire year if necessary) were averaged to estimate levels prevailing in 1984.

Water companies with significant contamination were required to sample more frequently, so that extrapolation was often not necessary. For systems in which monthly sampling occurred over part of the study period (e.g., Hawthorne, Wallington, Fairlawn, Garfield and Ridgewood), the categorizations of exposure using the algorithm were similar to the categorizations achieved by using the actual monthly data. After the initial exposure estimates for each town were completed, the estimates and the abstracted data that were used to produce the estimates were sent to BSDW for comment. After receiving comment from BSDW and revising the estimates accordingly, the package was then sent to the water companies for comment. In addition, each company was requested to answer specific questions about the particular characteristics of its own system and any sample data that appeared strange. All the companies responded to the mailing.

Some companies provided monthly water production logs. Many provided additional sample data. The water companies found numerous mistakes in the data abstracted from the hard copy A-280 database. In particular, many of the samples identified by the database as distribution samples were in fact "plant-delivered" or "raw water" samples. In some instances the company could not verify some of the samples in the database. The locations of samples were sometimes mislabeled.

The additional information obtained from BSDW and the water companies, including the corrected A-280 data, was used in the next round of exposure estimates. For those systems in which production logs were available, the contamination from each source (e.g., each well) was weighted by its contribution to the total supply.

Throughout the estimation process, it was assumed that complete mixing of the various supply sources occurred in the distribution system so that averages and weighted averages would be appropriate measures of exposure. (BSDW and the water companies concurred with this assumption.) After the next round of estimates were completed, the comment process was repeated. In addition, since the estimates were also to be used for the case-control study, we requested that each water company with a complex distribution system determine which part of its system served the block in which a case or control resided at time of birth. (For example, a system was deemed "complex" if it relied on several different wells with considerably different levels of contamination, or if a system supplied part of a town from groundwater sources and another part of town with a surface water source purchased from another company.)

This additional information was utilized to estimate exposures to cases and controls, but it was also used to make further revisions in the estimates used in the "cross-sectional" study. (For example, we learned from one company that a well that was sampled at a particular date was actually off-line at the time it was sampled and therefore could not contribute contamination to the distribution system. Therefore we revised the estimates to take this into account.)

6. DATA QUALITY

Although intuitively one would think that accuracy and precision would improve with increasing number of samples, this was not generally the case with the A-280 data. The systems which performed only the minimum number of samples required per year were almost always the systems with little or no detected contamination and no history of contamination problems. For these systems, the exposure assessment was easy, and probably very accurate.

The systems with more than the annual minimum sample dates required were those with contamination exceeding the MCLs. In addition, many of these systems utilized various wells with differing levels of contamination. For these systems there were two major sources of error and variability in the exposure assessment:

1) those expected in any environmental sampling; and

2) those peculiar to the A-280 Program and database.

In environmental sampling at one location, it is expected that contaminant levels vary over time due to migration, transformation, degradation, etc. Other sources of variability and error include inter- and intra-laboratory variability, differences in holding time and changes in sampling and analysis methods. Some water companies used different laboratory firms over the course of the study period, affecting the comparability of earlier and later samples.

For drinking water sampling at one location, an additional source of variability occurs due to changes in well production (if the sample is at the well) and changes in the mix of supplies (if the sample is from the distribution system). If sampling occurs at different locations, additional variability is introduced.

To assess the magnitude of the variability that would occur in the sampling of a contaminated groundwater supply using NJDEP-approved methods and NJDEP-certified laboratories, we analyzed 1989 data from two wellfields in

Hawthorne that were no longer in use. At each wellfield, two samples per month were performed.

At the North Station Wellfield, the mean TVOC contamination level was 16 ppb (s.d. = 4.9) and the coefficient of variation was approximately 30%. Levels ranged from 7 ppb to 26 ppb. Most of the variation (about 70% of the total sum of squares) was between-months, indicating some seasonal variation. The correlation between pairs of monthly samples was low (r = 0.42) and the "reliability" of the mean of the two measurements (based on Winer) was 0.60 and the intraclass correlation (the reliability of one measurement) was 0.43. It appeared that little was gained by taking two measurements per month.

At the South Station Wellfield, the mean TVOC contamination level was 15.7 ppb (s.d. = 3.1) and the coefficient of variation was approximately 20%. Levels ranged from 6.5 ppb to 20 ppb. Most of the variation (about 57% of the total SS) was within-month. The correlation between pairs of monthly samples was negative (r = -0.16), the reliability of two measurements was -0.24 and the intraclass correlation was -0.11. The differences between the pair of samples each month overwhelmed any seasonal differences.

Since the North and South Station Wellfields consisted of several individual wells each, the differences within month were likely due to two factors:

1) the wells in each wellfield had differing levels of contamination; and

2) the production of each well varied during a month so that the amount each well contributed to the overall mix of each wellfield varied during a month.

The 1989 Hawthorne data for the two wellfields represents a "best-case scenario" for a <u>contaminated</u> supply; i.e., samples of each wellfield were taken at the same location following strict NJDEP-approved methods, and the analysis was performed by a NJDEP-certified laboratory with years of experience in the program. Therefore it was expected that the variability of the data would not be considerable. (Of course, with a supply free of detectable amounts of contaminants, no variability would be expected and categorization of exposure would be straight-forward.) As expected, the variability of the data was slight so that each wellfield's contamination could be categorized with some confidence (i.e., in the "high" range: over 10 ppb). In addition, the wellfields had very similar mean levels of contamination.

Generally, the A-280 data for those companies with contaminated supplies displayed <u>substantially</u> more variability than the 1989 Hawthorne sample data. Therefore, it was considerably more difficult to categorize exposures for these systems. Additional information and assumptions were required so that the exposure categorization could be tailored to the unique features of each of these systems.

The sources of the variability in excess of what generally would be expected from drinking water sampling, lay in the peculiarities of the A-280 Program.

First, the location of the majority of distribution samples in the database was not provided so it was often impossible to know whether the same or similar location was being tested over time.

Second, the water company was required to sample at a point that was "representative" of its system but it was left to the company to decide the sample location. Some systems were so complex, that a particular distribution sample might be representative of only part of the company's system.

For example, a company might utilize various wells of differing water quality, each entering the system at a different point in the distribution system. If a sample was taken near the point at which a particular well's supply entered the system, that sample would best reflect the water quality of that well (although not exactly since some mixing would have occurred), <u>not</u> the distribution system as a whole. The sample may reflect levels of contamination that some residents in the town might be exposed to, but it would not reflect exposures to the vast majority of the town's residents who received a mixture from various wells.

Sample location is also a problem when a town utilizes two different sources of water: e.g., when one part of town is served primarily by groundwater sources, another part of town is primarily served by surface water supplies bulk purchased from another company, and the rest of the town receives a blend of the two supplies. If the company samples more frequently from the "surface water side of town", the levels of A-280 contaminants that most of the residents of the town are exposed to will be underestimated. The reverse will be true if sampling occurs more frequently from the "groundwater side of town".

The data in Table A1 are taken from actual A-280 data for the municipal water company of one of the towns in the study area. The wide variability in the sampling results are due to the problems mentioned above.

Table A1

1985 A-280 Data for Town X
(all levels in parts per billion)

DATE:	2/5	5/7	5/7	7/2	7/2	8/15	8/20	9/17
Sample Location:	D	D	D	D	P-well A	P-well A	P-well A	P-well A
TCE:	nd	4.8	nd	3.4	3.9	2.4	nd	3.1
PCE:	3.6	nd	4.8	7.2	nd	9.3	nd	4.3
DCE:	nd	nd	nd	23.0	35.0	29.0	nd	18.7
TCA:	nd	nd	nd	9.8	14.0	8.8	nd	nd
CTC:	nd	nd	nd	nd	nd	1.8	nd	5.5
benzene:	nd	nd	nd	nd	3.5	nd	nd	nd
TVOC:	3.6	4.8	4.8	43.4	56.4	51.3	nd	31.6

D: distribution system sample
P: sample taken at point where well enters the distribution system
nd: not detected
TCE (trichloroethylene); PCE (tetrachloroethylene);
DCE (dichloroethylenes); TCA (1,1,1-trichloroethane)
CTC (carbon tetrachloride); TVOC (total A-280 contaminants)

Table A2

1985 A-280 Data for Town X
(all levels in parts per billion)

DATE:	11/19	11/19	11/19	11/27	11/27
Sample Loca-tion:	D	P-Well B	P-Well C	P-Well B	P-Well C
TCE:	nd	15.0	nd	12.0	nd
PCE:	nd	10.0	2.7	8.6	3.3
DCE:	nd	11.8	nd	2.4	nd
TCA:	nd	11.0	2.0	12.2	nd
CTC:	nd	3.5	nd	nd	nd
benzene	nd	nd	nd	nd	nd
TVOC	nd	51.3	4.7	35.2	3.3

D: distribution system sample

P: sample where well enters the system

TCE: trichloroethylene

PCE: tetrachloroethylene

DCE: dichloroethylenes

TCA: 1,1,1-trichloroethane

CTC: carbon tetrachloride

(nd: not detected)

TVOC: total A-280 contaminants

In Table A2, all well samples were taken at the point where the well's supply entered the distribution system. All distribution samples were tap samples supposedly representative of the company's water quality.

Although it appears that data entry errors might explain the differences between some of the samples (e.g., the difference between the two D-samples for 5/7/85 in Table 1), it is assumed that this is not the case since the data were verified by the company.

Throughout 1985 wells A, B and C were in operation and no treatment or changes in well production occurred during this time. The company also purchased surface water supplies from another company to meet peak demands (e.g. during the summer months). This water was free of A-280 contaminants (although it had significant trihalomethane contamination).

During 1985, the distribution samples ranged from no contamination detected to a high of 43 ppb TVOC. The levels of the contaminants in the 7/2/85 D-sample were somewhat similar to the levels found in well A. The D-samples detecting no contamination were probably taken in the "surface water side of town". The D-samples detecting only PCE had similar levels to Well C. These samples may have been taken near Well C or may represent a mix in which surface water is the predominant component.

The TVOC levels in well A varied widely (from no detection to 56.4 ppb). In addition to the wide variability in the levels of TCE, PCE, DCE, TCA, CTC and TVOC, benzene was detected in only one of the samples. The sample data for Wells B and C are more consistent.

In order to estimate monthly exposures over 1985 (and 1984), it was first assumed that complete mixing of all water sources (wells and surface water) occurred in the distribution system and that most of the residents received this mixture. It was also assumed that each of the wells produced roughly the same amount of water and that this did not vary much over the year. Next, it was assumed that about two-thirds of the company's supply during the high demand summer months, and about one-fourth during the low demand winter months, came from surface water purchased from another company. Finally, it was assumed that the exposures during 1984 and 1985 were similar. (The company later concurred with these assumptions.)

Given the complexity of the system and the wide variability of the data, the algorithm mentioned previously was not used. Instead, the following procedure was used:

> The average levels of contamination for each well during 1985 were calculated. It was assumed that the 8/20/85 sample for well A was a "fluke" and therefore was not used to estimate the average levels for that well. It was further assumed that these averages reflected levels in these wells throughout 1984 and 1985. The overall mean of the contamination averages for each well was then used to characterize the groundwater component of the system.

The surface water component was assumed to be free of A-280 contaminants.

For each season of 1984-1985, the estimated proportions of the system contributed by the surface water and groundwater components were used to weight the A-280 contamination levels of each component.

The TTHM sample data for Town X's municipal water company was more reflective of the mix of water sources for each season, so simple averages of the four samples per season were appropriate.

The preceding example was not an extreme case. For example, another company serving a town in the study area, which had a supply that came from more than 10 public wells of widely varying levels of contamination, collected between 10 and 20 samples per month during the period 1985 through mid 1987 (thereafter, the company purchased water from another company). Wide variability were present not only between wells but also between samples (within month) for any given well. Unlike the previous example, well production logs were not provided by the company and the company could not specify the areas of the town primarily served by each well. Therefore information did not exist to perform weighted averages of each well's sample data. It was not clear to us that resistant measures of location such as the median would introduce less exposure misclassification than simple arithmetic averages of the monthly samples so the latter were calculated.

To summarize, in most instances, the availability of samples in addition to the two samples per year required by the A-280 program did not necessarily lead to a more precise estimation of contamination levels in a company's system. The A-280 data had to be supplemented by information from the company on well production and the areas of the town served by each well. Often, the presence of numerous samples in the database was simply indicative of a complex and polluted system that would require much work and judgment by the researcher to estimate exposure levels. Wide variability in contamination levels usually existed between wells in a system and over time for each well, so it was difficult to estimate with much confidence the actual levels of