Groundwater in Hawai'i

A Report on the Islands' Major Source of Drinking Water and How to Protect It

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NATURAL RESOURCES DEFENSE COUNCIL / 1993

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Report Purpose and Organization

The purpose of this report is to assess the extent to which there is currently a significant public health risk resulting from pesticides and industrial chemicals in Hawai'i's groundwater-based drinking water supplies, and to evaluate whether the state's existing groundwater protection efforts are adequate to protect Hawai'i's drinking water supplies from these contaminants in the future. Our review indicates that there is currently no conclusive evidence of widespread contamination of Hawai'i's groundwater-based drinking supplies, and that drinking water quality is generally good. At the same time, however, we found some reports of significant contamination incidents. Based on these reports, we believe that the potential for future contamination of drinking water supplies is a threat that should be taken far more seriously than is presently the case. Our review of the state's regulatory apparatus for protecting groundwater quality suggests that there is grave cause for concern about Hawai'i's ability to protect its groundwater sufficiently for drinking water purposes in the future, and that this concern applies equally to past, ongoing, and future releases of contaminants.

There is grave cause for concern about Hawai'i's ability to protect its groundwater sufficiently for drinking water purposes in the future.

In this introductory chapter, we describe the importance of groundwater in Hawai'i, summarize the extent of known contamination, describe the substances found to date and their potential health effects, and discuss the changes needed in order to prevent groundwater contamination from becoming a major problem in Hawai'i. Chapter 1 provides a detailed discussion of the known contamination to date, and Chapter 2 discusses the probable, possible and potential sources of contamination from activities that are likely to pollute groundwater, but for which no conclusive data are yet available. In Chapter 3, we assess the adequacy of the state's groundwater protection program, and offer our recommendations for changes needed in that program to provide real safeguards for the state's drinking water.

Importance of Groundwater in Hawai'i

In order to understand the importance of groundwater in Hawai'i, it is useful to have a working knowledge of the nature of the groundwater resource. Contrary to

Hawai'i's rocks and soils are highly permeable, thus potentially increasing the mobility of contaminants through the soil to ground-water.

popular belief, groundwater does not typically occur in underground lakes and streams. Instead, groundwater is found in saturated areas of sand, gravel, fractured rock, and cavernous limestone. Geological formations that are more permeable allowing for greater water movement-are known as aquifers. Groundwater moves both vertically and horizontally within an aquifer in response to differences in elevation and pressure. The movement is generally slow, sometimes only a few feet each year. Movement of contaminants within an aquifer can likewise be very slow, meaning that sometimes a decade or more can elapse between the time that a contaminant is introduced and when it is detected. Confined aquifers are those where groundwater movement is bounded on top and bottom by layers of less permeable material, and are usually less vulnerable to contamination than are unconfined aquifers.

Most of the groundwater resources in Hawai'i are located in basal water bodies, which are aquifers of fresh water floating on salt water, either freely or confined by coastal caprock under artesian pressure. Hawai'i's rocks and soils are highly permeable, thus potentially increasing the mobility of contaminants through the soil to groundwater above and beyond the rates experienced in many other areas with groundwater pollution problems.

Groundwater is an essential water supply source for most of the nation, with about half of the country's population depending on groundwater for its drinking water. In Hawai'i, the percentage is considerably higher, ranging from O'ahu, where 99 percent of the drinking water comes from groundwater, to Maui, where the percentage of drinking water derived from groundwater drops to seventy (KRP Information Services, 1990). About 46 percent of total water used for all purposes throughout the state comes from groundwater (Department of Health [DOH], 1990) (including agricultural and industrial uses as well as domestic).

Hawai'i's unusually high dependence on groundwater makes it that much more important to act protectively in order to maintain the quality of the resource. Unfortunately, however, Hawai'i's vulnerability to groundwater contamination has been realized only relatively recently. Consequently, systematic protective efforts have been slow in coming, as we shall see in this report.

Overview of Groundwater Contamination

* Groundwater contamination is a growing problem throughout the nation. At least 8,000 wells across the country have been shut down or severely affected by contamination by synthetic industrial and agricultural organic chemicals, inorganic chemicals including nitrates, and pathogens (Clean Water Action Project, et al., 1988). The sources of contamination include agricultural activities, municipal and industrial landfills, underground injection of a variety of wastes, subsurface sewage disposal Systems, transportation-related oils and greases leaked from pipelines, underground storage tanks and other disposed sources.

In Hawai'i, the extent of documented groundwater contamination is relatively limited compared to the widespread problems found in many other states. As will be emphasized throughout this report, however, the lack of extensive contamination findings cannot be a cause for complacency, because it is based on a relatively limited monitoring program. Indeed, NRDC believes that, given the limited extent to which groundwater monitoring has yet been conducted in Hawai'i, the level of contamination that has been uncovered thus far is cause for considerable concern.

In Chapters 1 and 2, we describe the results of our survey of information regarding groundwater contamination, both documented and potential.* The most information is available on agricultural sources of contamination. Since 1980, seventeen chemical contaminants of possible agricultural origin have been found "confirmed" in Hawaiian groundwater, and four chemical contaminants of possible agricultural origin have been found but not "strictly confirmed." (See Chapter 1 for an explanation of the difference between "confirmed" and "found but not strictly confirmed.") The detected chemicals include the now-banned pesticides, DBCP and EDB, and a host of other pesticides known to have harmful health effects. In some cases, the chemicals were detected in concentrations sufficient to necessitate the closing of groundwater wells, at one time affecting thirteen percent of the sustainable yield of the Pearl Harbor aquifer. (Some of the wells were subsequently reopened after the installation of costly water treatment facilities, as is discussed in Chapter 1.)

A greater number of contaminants thought to be from industrial sources have been identified in Hawai'i's groundwater, although there is less information about their concentrations or their exact sources. A total of twenty-one contaminants thought to be of industrial origin have been reported in Hawai'i's groundwater, twelve of which have been confirmed, and nine of which were found but not strictly confirmed. The detected substances include EDB, which has industrial as well as agricultural applications, benzene and toluene, all of which are known to be harmful to human health.

It should be emphasized that these findings encompass only the specific instances of contamination in Hawai'i about which there is a fair amount of scientific agreement. Our report focuses on the known contamination incidences for the obvious reason that they are the ones about which information is most readily available. However, these findings cannot be considered a complete picture of the state of groundwater quality in Hawai'i. It is important not to confuse the quality of knowledge presently available for a given contamination source with the actual magnitude of the contamination or health risk that may actually be associated with that source. Indeed, it could well be that a source for which there is yet only the barest amount of data in fact poses the greatest threat to public health.

Health Standards for Groundwater Contaminants

The concentrations of contaminants found in groundwater are typically very low, in the range of parts per million or billion (ppm or ppb), and the concentrations found to date in Hawai'i are no exception. Although it is unlikely that contaminant levels will reach acutely toxic levels in groundwater, chronic and widespread exposure to low levels of chemicals known to cause cancer, damage to the nervous system, birth defects, and other health effects is a serious concern. Most of the contaminants identified in Hawai'i's groundwater to date are thought to have at least one of these types of health effects if they are ingested over a long period of time at certain concentrations in drinking water. The Appendix lists the contaminants found in Hawai'i's groundwater, their potential health effects, and the applicable water standards or levels above which they are believed to be unsafe for human health.

Like that of other drinking water sources, the quality of groundwater supplies is intended to be safeguarded by the federal Safe Drinking Water Act, first enacted in

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*Our survey of reported Hawai'i groundwater contamination was limited to organic chemicals, and did not include other potential threats to drinking water integrity such as nitrates, saltwater intrusion or human pathogens.

1974. The law requires the Environmental Protection Agency (EPA) to establish numerical drinking water standards for public water supplies. Pursuant to this end, the law requires: 1) the identification of contaminants that may have an adverse effect on human health; 2) the determination of the maximum amount of each contaminant that could safely be consumed in drinking water; and 3) monitoring for, and public education about, the levels of chemicals in drinking water. Enforceable drinking water standards are known as "maximum contaminant levels" (MCLs). All public water supplies must be monitored for each specific contaminant for which there is an established MCL. If contamination occurs above the MCL, consumers must be notified.

Unfortunately, the development of MCLs for all the contaminants commonly detected in groundwater has been a slow process. MCLs have been adopted so far by the EPA for only twenty-two of the thirty-eight contaminants identified in Hawai'i's groundwater, as is shown in the Appendix. For those substances for which MCLs have not yet been adopted, two other standards are often looked at as a benchmark to evaluate the seriousness of groundwater contamination (although neither has any regulatory force). The first is the “lifetime health advisory” (LHA), which refers to the concentration of a contaminant at or below which adverse health effects would not be anticipated to occur, assuming exposure to the substance at that level over a seventy-year lifetime. LHAs can be developed by the EPA or individual states. The second standard sometimes used to assess public health impacts of groundwater contamination is the so-called "one-in-a-million" risk level, which EPA estimates for substances considered to be potential human carcinogens. A person drinking water with a contaminant at this level over a seventy-year lifetime would have "only' a one-in-a million chance of developing cancer from that exposure to the substance. The Appendix lists LHAs and one-in-a-million levels for some of the contaminants found in Hawai'i's groundwater.

Limitations of Hawai'i’s Groundwater Protection Program

In recognition of Hawai'i's heavy dependence on groundwater and its vulnerability to contamination, the Hawai'i Department of Health has prepared an official groundwater protection strategy. Our review of the strategy leads us to conclude that, while it contains many useful proposals for actions that could be taken to protect Hawai'i's groundwater, it is really a strategy to *develop* a strategy. It is not a strategy to implement measures that will actually protect Hawai'i's drinking water supplies. Given what we know about the groundwater pollution that has already occurred in Hawai'i and the potential for future contamination, the lack of an active state implementation strategy is disturbing.

In Chapter 3, we identify five major concerns about the state's adopted protection strategy. First, the state's current monitoring program relies far too heavily on drinking water wells as sampling points. Drinking water wells are often located far from likely points of pollutant origination and are typically drilled deeper than are monitoring wells. Thus, they are not ideal places from which to monitor groundwater pollution trends or to anticipate contamination of drinking water *before* it reaches a drinking water well. As is stated in the DOH Protection Strategy, "there are only a few site-specific observation wells throughout the State where the monitoring of water around potential contamination sources can actually occur: *therefore it is* currently *impossible to adequately assess and evaluate the impacts of these contaminant sources on* groundwater *quality'* (DOH, 1990, p. X-1, emphasis added).

Second, the state's protection strategy is ambiguous about the level of protection that is intended for currently unused and/or unpolluted aquifers. While current drinking water sources should certainly receive the highest priority for protection efforts, we are concerned that the ambiguous goal may allow deterioration of aquifers that could be important drinking water sources in the future. *

Our third concern about the adopted strategy is that it appears to downplay the significance of reported findings of groundwater contamination. The findings are presented only as a series of points on maps of each of the islands, and no analysis is provided of their meaning. The effect of the presentation is to trivialize the impact and significance of the reported findings. ***

Our final two criticisms of the adopted strategy relate to its lack of a clear plan to develop protective measures, and the lack of an effective public participation program. The Protection Strategy does discuss the need to adopt actual protective measure, but it does not provide a process or schedule for assessing what measures are needed or to conduct the administrative tasks necessary for their adoption. Similarly, the Strategy does not provide for an ongoing program for public education and participation, which is needed in order for the public to understand the dimensions of the problem and provide support to DOH in its efforts to safeguard Hawai'i's groundwater.

Recommendations for Hawai'i's Groundwater Protection Program

NRDC recommends that DOH take the following actions in order to strengthen its groundwater protection program. First, we recommend that DOH take every step possible to participate in an expanded monitoring program that would allow the sampling of groundwater at selected points in addition to drinking water wells. Second, NRDC urges DOH to develop immediately a work plan for the adoption of preventive measures. Third, DOH should adopt an unambiguous goal of non-degradation for all groundwater resources in Hawai'i. Last, we recommend that DOH develop a broad-based, ongoing public education and participation program so that the public will have a rational and complete understanding of the nature of the threat and the steps that are needed to safeguard Hawai'i's groundwater. *

There's more . . . please keep going . . .

There's more . . . please keep going . . .

Chapter 1: Findings of Groundwater Contamination in Hawai`i

Until the last decade, there were relatively few known instances of groundwater contamination in Hawai'i, and those that were known were generally believed to be isolated occurrences, not part of a larger trend or problem. Perhaps due to this belief, the state has been slow to develop a monitoring system capable of determining the actual extent of any groundwater contamination problem. While the known sources of contamination do not currently constitute a widespread public health risk, they do indicate the potential for such a risk and suggest the need for a more effective trend monitoring program to protect drinking water supplies in the future.

The available evidence indicates that at least twenty-four and likely as many as thirty-one distinct contaminants have been detected in Hawai'i's groundwater. That is, twenty-four substances have been "confirmed" in Hawaiian groundwater, and an additional seven have been reported but are presently categorized as "not strictly confirmed."* Of these thirty-one, twenty-nine have been detected on O'ahu, seven on Maui, five on Hawai'i, and four each on Kaua'i and Moloka'i. In addition to these thirty-one contaminants, seven other hazardous substances are suspected but as yet are unconfirmed as groundwater contaminants in Hawaiian groundwater. The complete, island-by-island listing of these various contaminants is contained in Table 1-1. As is discussed in more detail later in this chapter, the contaminants have been discovered at varying concentrations-in some cases they have been barely detectable, while in other instances concentrations have greatly exceeded relevant state and federal health protection standards.

The origins of these substances appear to be roughly divided between agriculture and industry, although the source of contamination is not always clear. In at least several instances, it appears -that a given contaminant has both agricultural and industrial

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* Confirmed contaminants are those which have been explicitly confirmed with a confirmation test or which have been found at a site where the contaminants have been previously found. Other contaminants have in many areas been detected but have not had confirmation tests performed and thus are not strictly confirmed.

Table 1-1. Groundwater Contamination Detected in Hawai'i, by Island

O'AHU

*Confirmed** - 1,2-DCP, 2,4-D, Aldrin, Ametryn, Atrazine, Bromodichloromethane, Bromoform, Carbon Tetrachloride, Chlordane, Chloroform, DBCP, DCE, DDT, Dibronwchloromethane, Dieldrin, EDB, Lindane, PCE, TCE, 1,2,3-TCP

*Not Strictly Confirmed, but Assumed Reliable** -DCE, Benzene, Toluene, Xylene, 1,1,2-TCP, 1,2,2-TCP, PhenolT, Dichloropropenes, PCE

*Unconfirmed** - Aldrin, Ethylbenzene, Methylene Chloride, Freon, Freon II

KAUA'I

*Confirmed** - Atrazine, Ametryn, Simazine, DBCP

*Unconfirmed** - Toluene, Ethylbenzene

MOLOKA'I

*Confirmed** - Bromoform, Chloroform, Bromodichloromethane, Dibromochloromethane

*Unconfirmed** - ethylene Chloride, Trichlorofluoromethane, Freon II

LANA'I

*Unconfirmed** - Atrazine

MAUI

*Confirmed** - TCP, DBCP, EDB, DCP, Atrazine, PCE

*Not Strictly Confirmed, but Assumed Reliable** - Simazine

HAWAI'I

*Confirmed** - Atrazine, Hexazinone, PCE, Ametryn, Diethylphthalate

*Unconfirmed** - Dichlorobenzene, Ethylbenzene, Toluene, Methyl Chloride

Sources: Lau 1991; DOH 1990; DOH 1989b; DOA 1989; and Giambelluca, Leung and Konda, 1987.

* Confirmed contaminants are those which have been explicitly confirmed with a confirmation test or which have been fund at a site where the contaminants have been previously found. Other contaminants have in many areas been detected but have not had confirmation tests performed and thus are not strictly confirmed.

al origins. In most cases, the available data for chemicals of agricultural origin and their fate in the environment are of better quality than those of industrial origin.

One of the consequences of the comparative dearth of attention paid to industrial sources of contamination is that the available data are generally of poorer quality than for agricultural sources. Most often, the data indicate only whether a given contaminant was or was not detected; less often are data available that indicate that a legal contamination limit has been exceeded; least often do the data actually indicate by how much a legal limit has been exceeded. The situation for agricultural contamination is somewhat better, but even here the data are far from adequate for the purpose of estimating with any reasonable degree of confidence the overall magnitude of the associated groundwater contamination problem.

In order to prevent further groundwater contamination in the future, it is clearly necessary and urgent that we develop a better understanding of the extent of the present contamination problem, contamination pathways and trends, and the physical properties of the chemicals being used, including their persistence and mobility in low concentrations.

Mounting evidence of contamination by agricultural chemicals no longer permits us to be complacent. Since 1980, seventeen chemical contaminants of possible agricultural origin have been found "confirmed."

Agricultural Chemicals

Agricultural chemicals have been used in Hawai'i since the mid-1940's (Lau 1987), and up until about 1980, there was very little fear of groundwater contamination. The prevailing attitude was sumrned up by Oki, et al.:

> Prior to the recent discoveries of pesticides in the state's groundwater, it was felt that the great depth (hundreds of meters) between the ground surface and basal waters of the state's aquifers was sufficient to prevent leaching of pesticide residues to the water tables. Furthermore, it was believed that any residues, which did reach the basal aquifers, would become so greatly diluted as to be undetectable. (1990, p. 12)

However, mounting evidence of contamination by agricultural chemicals no longer permits us to be complacent. Since 1980, seventeen chemical contaminants of possible agricultural origin have been found "confirmed" in Hawai'i's groundwater, and four chemical contaminants of possible agricultural origin have been found but not "strictly confirmed" (see Table 1-2). The detection of these chemicals - some in concentrations sufficient to result in the closing of groundwater wells, affecting 13 percent of the sustainable yield of the Pearl Harbor Aquifer - provides compelling evidence of the vulnerability of Hawai'i's groundwater resources to contamination.

Initial detection of pesticides in Hawai'i appears to be a result of monitoring conducted in response to suggestions in 1979 by the U.S. Environmental Protection Agency (EPA), which was concerned about dibromochloropropane (DBCP), a pesticide responsible for widespread groundwater contamination in California (Lau 1987). Through this initial monitoring, the Department of Health essentially stumbled on to other contaminants, finding considerable contamination in a very short period of time. Thus far, responsive actions have been limited to remedial measures to protect public health, and these measures have been costly.

The fact that pesticides have been discovered in the groundwater relatively recently does not mean that the contamination was itself a recent occurrence. Contaminants tend to disperse downward from the surface at a slow rate and are often not detected for a long time - particularly when detection is available only from drinking water

TABLE 1-2. GROUNDWATER CONTAMINANTS OF POSSIBLE AGRICULTURAL ORIGIN

Confirmed*

- **1,2-DCP (1,2-dichloropropane)**
- **2,4-D (2,4-dichlorophenoxyacetic acid)**
- **Aldrin**
- **Ametryn**
- **Atrazine**
- **Carbon Tetrachloride*****
- **Chlordane*****
- **DBCP (1,2-dibromo-3-chlompropane)*****
- **DDT (dichlorodiphenyltrichloroethane)*****
- **Dieldrin**
- **EDB (ethylene dibromide)*****
- **Hexazinone****
- **Lindane**
- **PCE (tetrachlomethylene)**
- **Simazine****
- **7CE (trichloroethylene)**
- **TCP (1,2,3-trichloropropane)**

Not Strictly Confirmed, but Assumed Reliable*

- **Benzene*****
- **1,1,2-TCP (1,1,2-trichlompropane)**
- **1,2,2-TCP (1,2,2-trichlompropane)**
- **Dichloropropenes**
  - **(2,3-dichlo@l-propene) or**
  - **(1,2-dichlom-l-propene)**

*Confirmed contaminants are those which have been explicitly confirmed with confirmation test or which have been found at a site where the contaminants have been previously found. Other contaminants have in many areas been detected but have not had confirmation tests performed and thus are not strictly confirmed.
**These chemicals have been detected only on the outer islands; the rest have been found on O'ahu and in some cases on the outer islands as well.
***Some chemicals, such as chlordane, EDB, DBCP, and DDT have been recently banned but are recognized as agricultural chemicals. Others, however, like benzene and carbon tetrachloride are old components of fumigants. They are not generally recognized as agricultural chemicals, but may also be of agricultural origin.

Sources: Oki and Giambelluca, 1985; Giambelluca, Leung, and Konda 1987.

wells, which are typically sunk very deep into the groundwater. Moreover, breakthroughs in water quality monitoring technology now allow us to detect chemicals in concentrations much lower than previously possible. Thus, some chemicals may have been present in Hawai'i's groundwater in low concentrations for a considerable time and gone unnoticed. Two organic chemicals, ethylene dibromide (EDB) and trichloropropane (TCP), have been found in relatively steady concentrations at levels above present Hawai'i health standards at several sites since the first samples were taken. DBCP levels have also been above health standards since the first analyses
**** for these- chemicals were conducted and have been rising steadily ever since. This raises the question of how long the water supply had been contaminated with chemicals at these levels before the problem was discovered and remedial measures taken.

History of Pesticide Contamination in Hawai'i

The three chemicals that dominate confirmed reports of groundwater contamination in Hawai'i are ethylene dibromide (EDB), dibromochloropropane (DBCP), and trichloropropane (TCP). EDB and DBCP are volatile, organochlorine pesticides formerly used by pineapple growers to kill nematodes, root-feeding microscopic worms highly destructive to numerous agricultural crops. TCP is believed to be an impurity in another nematicide, Shell D-D. All have a history of causing groundwater contamination in other states. EDB and DBCP are currently banned by the U.S. Environmental Protection Agency (EPA) from further usage in Hawai'i or elsewhere.* But the fact that they are no longer in use does not mean that we should not be concerned about their presence in Hawai'i's groundwater-in fact, in some cases they were not detected until after the bans were in place.

Kunia *Well EDB* and *DBCP Spill*

The first known occurrence of groundwater contamination by pesticides in Hawai'i apparently resulted from a major spill of EDB, near Del Monte Corporation's Kunia well (a domestic water supply well) in April 1977. Approximately 495 gallons of the pesticide were spilled at a mixing and loading site within 60 feet of the well (Pringle, Liu, and Green 1984; Lau 1987; Oki and Giambelluca, 1985). Apparently, the pesticide also contained as an impurity a small fraction (0.25%) of DBCP (Pringle, Liu and Green 1984). The EDB was not detected in groundwater nearby the Kunia well until several years later.

About one week after the spill occurred, the Hawai'i Department of Health (DOH) analyzed groundwater from the well, but found no detectable EDB at a detection level of 500 ppt (parts per trillion) (Oki and Giambelluca 1985). Apparently, there was no analysis for DBCP (Mink, 1981). Testing was conducted at the well in June and August of 1979 by Del Monte for DBCP, but, on both occasions, duplicate samples revealed what were considered ambiguous results: a positive and a non-detectable result for DBCP (Oki and Giambelluca, 1985) (Oki and Giambelluca do not state whether analyses were conducted at that time for the main spill constituent, EDB.) But in April and May of 1980, test results of a joint sampling program by the Hawai'i Department of Agriculture, Hawai'i Department of Health (DOH), and the Pineapple Growers' Association of Hawai'i revealed very high levels of EDB at the Kunia well (92,000 to 300,000 ppt), and DBCP (500 to 14,000 ppt) (Giambelluca, Leung, and Konda 1987), with a detection limit at the DOH laboratory of 50 ppt for DBCP and 100 ppt for EDB (Oki and Giambelluca, 1985). (Current DOH MCLs for the two chemicals are 40 ppt for EDB and for DBCP.) Even though at that time no enforceable action levels existed for EDB or DBCP, the Kunia well was closed by DOH on April 25, 1980, due to the high contamination levels (Honolulu *Advertiser*, April 26, 1980). Other water wells near the Kunia well spill site were also

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In 1979, the EPA suspended registration of DBCP for all uses except for pineapple in Hawai'i (Pringle, Green, and Liu, 1984). The granted exemption was due to the unique hydrological characteristics pertinent to Hawai'i's basal groundwater (Mink, 1979). The pineapple industry on O'ahu reportedly stopped using DBCP on a voluntary basis in 1977, but DBCP was still apparently used on Maui until 1985 (Lau, 1987). In 1985, the EPA officially cancelled the last remaining legal use of DBCP (for pineapple in Hawai'i), and prohibited the use of remaining stock.

In 1983, all registration of EDB as soil fumigant was cancelled by the EPA, and in 1984, the remaining use of EDB, for the fumigation of domestic fruit (citrus and papaya), was also banned (DOA, 1989).

found at the same time to be contaminated with extremely high concentrations of EDB (up to 30,000,000 ppt) and high concentrations of DBCP (up to 10,000 ppt) (Giambelluca, Leung, and Konda, 1987), but apparently, no action was taken on these wells. ****

While at the time, the contamination of the Kunia well was considered to be the result of the single large spill, it has been suggested that previously occurring smaller spills at the mixing and loading site (Lau, 1987) may have also contributed to the problem. Using simulation modeling, Liu et al. (1983) concluded that the contamination may have been due to leakage from a nearby long-term pesticide storage site in a small gully where drums of EDB and DBCP were stored on the ground, but more research was needed to substantiate these results (Pringle, Liu, and Green, 1984). However, the high levels of EDB and DBCP found at Del Monte's Kunia well in April 1980 -- only eight months after recording ambiguous results in August 1979 -- suggest that the Kunia well contamination was the result of a large amount of contaminant moving through the soil profile. Thus, the single large spill appears to be the most likely cause of the high levels of contamination.

Other Point Sources of pesticide Contamination

The EDB and DBCP spill at the Del Monte site and the resulting contamination. of very high pesticide concentrations point to the enormous consequences of mixing and loading accidents and the potential problems that everyday pesticide mixing and loading operations can have on groundwater quality. A study of such sites by the Hawai'i Department of agriculture (DOA) concluded that pesticide mixing, loading, and transferring procedures at virtually all the pesticide mixing and loading sites surveyed on O'ahu may contribute to groundwater contamination. Based on the proximity of those sites to contaminated wells, the DOA attributes much of the contamination to those sources: "The close proximity of pesticide contaminated wells to the primary mixing/loading sites of Del Monte, Dole, and Oahu Sugar Cos. indicates a strong likelihood of ground water contamination from the mixing activities at these sites. Past and current pesticide mixing activities by these plantations have resulted in the discharge of undiluted, leachable pesticides directly onto soil sediments in close proximity of ground and well water reserves" (DOA 1989b, pg. 34).

But the DOA concluded that pesticide mixing and loading practices were not the only sources of contamination: "An equal hazard to ground water supplies on Oahu appears to result from the field application of certain highly leachable pesticides such as Atrazine. This is indicated by the dispersed nature of contaminated wells in the Wai [a] lua area, which are not located in close proximity to mixing/loading sites" (ibid.).

Further Contamination from EDB and DBCP

In 1979, widespread DBCP contamination of California groundwater (DOA, 1989) prompted EPA to ask Hawai'i, as one of five states where DBCP was then in use, to test for DBCP in its groundwater (Oki and Giambelluca, 1985). In response to the EPA's request, DOH tested sixteen well sites in pineapple fields on O'ahu, Moloka'i, Maui, and Lana'i, and all showed negative results with a detection limit of 130 ppt (Oki and Giambelluca 1985; Lau, 1987). However, as will be seen below, unrelated testing in that same year found DBCP at concentrations of concern at four sites on Maui, and subsequent testing in later years found a number of incidences of both DBCP and EDP contamination at various sites. The more serious occurrences of reported contamination (primarily of drinking water wells), are collected from several different sources, and arranged chronologically below. Many more wells, mostly irrigation wells, have also been contaminated, but have been far less publicized.

Between April 1980 and July 1983,12 wells were closed statewide, 10 of which were in O'ahu, due to EDB and DBCP contamination, affecting a substantial portion of Honolulu's and central O'ahu's water supply. *

- June - August 1979: Four sites n Maui were found to be contaminated with DBCP at levels equal to or greater than the EPA MCL of 200 ppt - Maui High School well, 200 ppt; Pfaeltzer's Cove Spring, 2230 ppt; Ka'opala Spring, 260 ppt; and a perched water sample from Makilo Gulch, 1740 ppt (Oki and Giambelluca, 1985). - May 1980: two irrigation wells in Wailua were found to be contaminated with 20 to 37 ppt DBCP; they were not closed because they were not potable water sources (Oki and Giambelluca, 1985).
- April 1980: EDB was detected on Maui at a concentration of 100 ppt, or double the EPA MCL, at a perched water well in Makilo Gulch (Oki and Giambelluca, 1985). - July 1981: DBCP was found at 211 ppt at the Moloa'a Tunnel, a municipal water supply on Kaua'i (Giambelluca, Leung, and Konda, 1987). The well was apparently not closed until two years later (Pringle, Liu, and Green, 1984), at which time, analysis at the well showed a DBCP level of 190 ppt (Giambelluca, Leung, and Konda, 1987).
- February 1981: DBCP was reported in wells in Mililani and Waipahu (Giambelluca, Leung, and Konda, 1987).
- September 1982: Further testing prompted the Honolulu Board of Water Supply (BWS) to close Mililani Well 11, Pump 5 due to DBCP contamination of 97 ppt. - July 1983: Eight more municipal wells in central O'ahu were closed due to EDB or DBCP contamination.
- July 5, 1983: Waipahu Wells, Pumps 3 and 4, were closed by BWS, due to EDB levels of 50 and 70 ppt respectively (Oki and Giambelluca, 1985). - July 7, 1983: Waipahu Wells, Pumps I and 2 were shut down by BWS due to EDB concentrations of 18 and 26 ppt (ibid.).
- July 14, 1983: Kunia Wells II, Pumps 1 and 2 were closed by the BWS due to DBCP contamination of about 20 ppt (*Honolulu Advertiser*, July 15, 1983).
- July 19 and 20, 1983: Mililani Wells I, Pumps 2 and 4, were closed after sampling detected DBCP at concentrations of 30 and 40 ppt, respectively (*Honolulu Advertiser*, July 20, 1983, and July 21, 1983). *
- July 1983: The Moloa'a Tunnel well on Kaua'i, and Maui High School well on Maui were closed due to findings of DBCP contamination of 190 ppt and 140 ppt, respectively (Pringle, Liu, and Green, 1984).
- July 1983: Also reported contaminated by DBCP in July 1983, but not closed, were Mililani Wells I (Pumps 1 and 3) and Wiawa Shaft, a major water source for the U.S. Navy. All had DBCP concentrations reported between 20 and 40 ppt. These wells were not closed, despite the fact that the DOH's maximum contaminant levels (MCLS) for EDB and DBCP were 20 ppt at that time for both pesticides (Lau, 1987). Apparently, the wells were allowed to remain open due to the lack of alternative potable water sources for these areas (Oki and Giambelluca, 1985; BWS, pers. comm.).
- March 1985: EDB was found at four sites-Maui High School well site at a concentration of 65 to 67 ppt; Pa'uwela Spring at 1200 ppt; at HC&S Pump 17 in upper Paia (Oki and Giambelluca, 1985); and at HC&S Pump 18 in Pu'unene at a concentration of 47 ppt (Giambelluca, Leung, and Konda, 1987).

* Thus altogether, between April 1980 and July 1983, a total of twelve wells were closed statewide, ten of which were on O'ahu, due to EDB and DBCP contamination, affecting a substantial portion of Honolulu's and central O'ahu's water supply. The out-

*Another Mililani well that was under construction (No. VI) was not opened (as of 1984) due to contamination (Pringle, Liu, and Green, 1984).

Much of the EDB contamination on O'ahu is in a localized area near Waipahu, down-gradient of a military oil and lubricant pipeline, which has been * known to have numerous leaks ranging from tens to hundreds of thousands of gallons of fuel.

right closures from the most contaminated wells withdraw approximately 13 million gallons per day (MGD) from central O'ahu's water supply (Lau, 1987), or about 5.8% of the already fully allocated sustainable yield estimate of 225 MGD of the Pearl Harbor aquifer, the principal source of water for O'ahu (Lau, 1987).

Another approximately 16 MGD from the U.S. Navy's Waiaw Shaft (1983 pumpages estimated from Oki et al., 1990, pg. 401), or 7.1 % of the sustainable yield estimate from the same aquifer, was contaminated above the Hawai'i MCL of 20 ppt for, DBCP, as were the two Mililani Wells, Pumps 1 and 3. Thus, at least 13% of the sustainable yield * (29 MGD) of the Pearl Harbor Aquifer was contaminated above the Hawai'i MCL, over half of which was nevertheless supplied as public drinking water by the U.S. Navy and BWS due to the lack of alternative sources.

In an effort to restore to service much of the needed 13 MGD, the Honolulu Board of Water Supply spent $9,000,000 to drill new wells and to build three water treatment plants with granular activated carbon filters in Waipahu, Mililani, and Kunia. The Mililani treatment plant (which was funded by private developers) came on line in March, 1986, the Kunia Plant in May 1986, and the Waipahu plant in September 1987 (BWS, pers. comm.). However, higher than expected concentrations of dichloropropane (DCP, a component of other pesticides, D-D and Telone II) at the Mililani plant may eventually force the installation of an air stripper at an additional expenditure of $2,300,000 (DOH, 1990). Thus, the remedial actions may cost in excess of $1 1,000,000 and take the better part of a decade to complete since the dates of well closure. The air stripper is apparently still under consideration. The present practice is to change the carbon at this site as soon as DCP is seen in the effluent water. Before the increased levels of DCP were discovered, the carbon in the filters was to be replaced once a year. To account for the increased DCP levels, the carbon is now changed three times a year (BWS, pers. Comm.).

Contamination from TCP *

Another agricultural chemical that has contaminated groundwater elsewhere, trichloropropane (TCP), has also been discovered in Hawai'i's groundwater at toxic concentrations. TCP is typically found as an impurity in D-D (dichloropropane - dichloropropene), which was used quite extensively as a nematicide by the pineapple industry in Hawai'i between at least 1947 and 1977 (Lau, 1987). Groundwater testing for TCP was not started until 1983, but at that time TCP was found in 9 out of the 10 central O'ahu well closure sites in concentrations of between 300 ppt and 2800 ppt (Oki and Giambelluca, 1985; Lau and Mink, 1987), substantially above the EPA LHA level of 60 ppt. Because no health hazard data were available for TCP at the time, TCP concentrations were not reported along with EDB and DBCP (Lau and Mink, 1987), and presumably were not used as a criterion for well closure. TCP has also been found in numerous other water samples from O'ahu: the U.S. Navy's Waiawa Shaft, the five wells in Ho'ae'ae and two wells in Waipi'o, as well as other sites (Oki and Giambelluca, 1985). TCP was also found at the Maui High School well site at levels of 340 to 460 ppt in November 1983 (Oki and Giambelluca, 1985).

Other Possible Sources for EDB and TCP

In addition to its uses in agriculture, EDB also has military and industrial applications, primarily, a "lead scavenger" in leaded gasolines (Lau, 1987). Much of the EDB contamination on O'ahu is in a localized area near Waipahu, down-gradient of military oil, and lubricant (POL) pipeline, which has been known to have had numerous leaks ranging from tens to hundreds of thousands of gallons of fuel. The POL pipeline is the most likely cause of the Waipahu contamination (see Industrial

Chemicals section of this chapter). It should be noted, however, that EDB has been confirmed in boreholes up gradient from the POL pipeline, in wells in Kunia (probably related to the EDB spill of 1977) and on Maui. These sites have no hydrological relationship to the military POL pipeline, which suggests that agricultural sources were responsible for these occurrences of EDB contamination. Thus, both agricultural and industrial sources have caused EDB contamination in Hawai'i.

TCP is found in industrial products such as paint and varnish removers, and degreasing agents, and thus there is likewise a possibility that some or all TCP contamination is due to industrial rather than pesticide use (Lau 1987).

Potential for Further Contamination from Agricultural Chemicals

Contamination levels of previously banned chemicals in agricultural use show no significant decreases despite the passage of up to 14 years since the chemicals were last used. In fact, DBCP and TCP are both still being found at increasing concentrations at some sites. As will be seen below, it is difficult to interpret trends at known contamination sites because in most cases monitoring is performed on water samples taken from mixed sources and because the data set is very small. Since monitoring of other sites is very limited, we do not yet know to what extent these now-banned chemicals remain in Hawai'i's groundwater as possible threats to our drinking water. ****

Contamination Trends of Previously Used Chemicals (EDB, DBCP, TCP, and DCP) at Known Contamination Sites

Since the initial discoveries of contamination in the early 1980s at the three severely contaminated sites described above (Waipahu, Mililani, and Kunia), there is no evidence of a decrease in contamination levels. If anything, the data suggest that levels may still be increasing for some chemicals at both Mililani and Kunia. ****

DBCP has been increasing steadily at the Mililani Wells since the initial reports of contamination in 1983. DBCP concentrations at the six Mililani Wells in 1983 averaged about 25 ppt and rose to slightly over 50 ppt by 1987. DBCP concentrations at the influent to the Mililani Wells GAC filter increased still further to 80-90 ppt by 1991 (Lau, 1991). TCP concentrations from the six Mililani Well pumps and GAC influent water from 1.984 through 1991 show that TCP levels have been staying level at roughly 2000 ppt (varying from 1000 ppt to 3000 ppt) (substantially higher than the EPA LI-IA of 60 ppt) for the entire time period (Lau, 1987). ****

DBCP has been increasing steadily at the Mililani Wells since the initial reports of contamination in 1983. *

Data on dichloropropane (DCP) levels at the Mililani wells are sparse. In 1983, some samples found no detectable or quantifiable DCP, while another showed a concentration of 287 ppt and one analysis showed 800 ppt. Analyses from only three GAC-influent samples in late 1989 were 793 ppt, 617 ppt, and 1,036 ppt (BWS, 1991). Further analyses in 1990 and 1991 show levels between 1,000 and 1,300 ppt (DOH, pers. comm.). These concentrations are all below the EPA MCL of 5,000 ppt.

At the Kunia and Waipahu wells, pesticide levels have remained high, although they do not appear to be continuing to rise. DBCP from the two pumps at the Kunia Wells II averaged about 23 ppt in late 1983. Influent water to the GAC filter showed a slightly decreased DBCP concentration to about 20 ppt by mid-1987. Since September 1988, DBCP concentration at the influent to the filter has been below the detection limit of 20 ppt. TCP concentrations at the Kunia well have shown a similar very slow decreasing trend. TCP concentrations in about late 1983 were ranging between 800 and 1100 ppt (averaging about 900 ppt) (Lau, 1987). From 1987 through 1990 concentrations fluctuated between 600 and 970 ppt (averaging about

800 ppt) (BWS, 1991). From 1983 to 1987, TCP concentrations at Kunia Wells II increased from an average of about 300 ppt to 350 ppt.

EDB at the 4 pumps at the Waipahu wells averaged about 50 ppt in mid-1983 and increased to about 90 ppt by December 1984 (Lau, 1987). EDB at the influent to the Waipahu Wells GAC filter in late 1987 ranged between 60 and 110 ppt (averaging about 85 ppt) (Lau, 1987). By 1990, EDB levels had decreased and were fluctuating between below the detection limit and 59 ppt (averaging about 40 ppt) (BWS, 1991). TCP at the 4 pumps between late 1984 and late 1985 ranged between 160 and 300 ppt (averaging about 225 ppt). From mid-1987 to late 1990, TCP levels fluctuated between below 200 ppt and 400 ppt (still averaging about 225 ppt) (BWS, 1991).

The scientific and regulatory value of the information from the post-1986 water samples is lessened somewhat by virtue of the fact that these samples are now taken from the influents to the granular activated carbon (GAC) plants that treat the water from these three well sites. The influent to the treatment plants is drawn from different wells from within the fields at different depths; the concentrations reported are thus not strictly comparable to the levels originally found at
**** these sites. Moreover, the blending of water samples from several pumps may mask "hot spots" within the well field of particularly high concentrations and offer little assistance in the detection of pesticide plume movement. However, the overall trend showing continued high levels of pesticides at all three sites is still very apparent despite these ambiguities. Further, due to the current DOH practice of monitoring only drinking water wells, little can be said about the majority of wells (non-drinking water wells) where EDB, DBCP, and TCP contamination has been found.

Potential Additional Contamination from Banned Chemicals

**** The potential for further findings of contamination from already banned pesticides remains significant, as it is highly possible such chemicals have migrated or are migrating to areas of the aquifer that are not now used and/or monitored. Contrary to common belief, many of these chemicals do not degrade quickly.

One measure of a chemical's persistence in the environment may be approximated by its half-life, the amount of time required for one-half of the original quantity to break down. For instance, DBCP's half-life in groundwater at 25 degrees C is roughly 38 years, but at 15 degrees C it is roughly 141 years (Pringle, Liu, and Green, 1984). (Hawai'i's groundwater temperature averages 20 to 22 degrees C.)

The amount of time a contaminant will stay in groundwater is dependent on such factors as the persistence of the chemical and the rate of flow of groundwater to the ocean. As a general rule, groundwater flows very slowly under normal gradients - in central O'ahu, only about 4 feet per day (Lau, 1987). Hufen, Eyre, and McConachie (1980) have concluded that much of Pearl Harbor aquifer (those portions that are down-gradient from pineapple production) had residence times in excess of 200 years. This implies that any contaminants that enter the groundwater system can
** persist for decades or longer if they have a long half-life.

***** !!!!! Combined BWS and DOH monitoring does not analyze for the vast majority of the pesticides presently used in Hawai'i that could be a risk to public health. This leaves open the possibility that the public could be exposed to chemicals for substantial periods of time without recognition of a potential problem (e.g., TCP at the Mililani Wells). Even if we could monitor for all known chemicals, the present monitoring of only potable water supplies, which originate deep in the aquifers, does not provide enough lead time to prevent a minor contamination problem from becoming a major crisis requiring remedial action. (This issue is addressed at length in Chapter 3.)

Current Monitoring and Research Efforts Related to Pesticide Contamination of Groundwater

The Honolulu Board of Water Supply takes monthly samples for EDB, DBCP and TCP from the influents and effluents at the GAC filter plants at Kunia, Waipahu, and Mililani, and for DCP at Mililani. It also monitors for these pesticide-related compounds at other water sources that have been known to have detectable concentrations of these chemicals in the past. DOH operates a groundwater monitoring program, conducted out of the Safe Drinking Water Branch, which monitors for 8 regulated and 40 unregulated chemicals (almost all of which are non-agricultural-related solvents) at approximately 500 drinking water wells state-wide in a three-year rotating cycle. Every year, four quarterly samples from the same 150 wells or so are analyzed for the 48 chemicals. At one point, DOH was also taking samples from non-drinking water wells, but this program was dropped, apparently in order to save money (DOH, pers. comm.).

Several joint research projects between the Hawaii Department of Agriculture and the University of Hawaii are currently under way to research these unknowns. According to DOA, several highly leachable pesticides, such as atrazine, are being tested on Hawai'i soils (DOA, pers. comm.). HNRIS, a geographical information System, is currently being used to evaluate Hawai'i's agricultural regions potentially vulnerable to contamination by specific pesticides (DOA, pers. comm.).

It is not too late to establish a strong program that will protect the majority of Hawai'i's drinking water supplies.

Conclusions

A decade prior to the first discoveries of pesticide groundwater contamination in Hawai'i, hydrologists had warned that contamination due to normal application pesticide use was possible, and that monitoring and research with respect to Hawai'i's environmental conditions was necessary.

Green and Kanehiro (1970) stated, "Hawaii's latisolic soils have unusually high infiltration rates, due in part to the good stability of soil aggregates which resist deterioration by cultivation and rainfall impact. The permeability of these soils is conducive to low runoff and erosion, but may also result in rapid leaching of chemicals through the profile to ground waters.... Several pesticides used in Hawaii might be considered potentially hazardous to either soil or water quality... Highly mobile and persistent materials such as bromacil may threaten ground-water quality under conditions of high rainfall or irrigation...." (page 7).

The authors further warned that, "The present freedom of Hawaii's soils and waters from serious pollution to agricultural pesticides is no reason for complacency" (ibid., page II). While these warnings were not heeded in time to prevent the first round of groundwater contamination in the 1980s, it is not too late to establish a strong program that will protect the majority of Hawai'i's drinking water supplies from a repetition of these problems.

There are many unknowns relating to the agricultural chemicals we use, the soils we use them on, and the distribution of the present contamination situation. Considering that the land-use practices that are responsible for the present contamination problem have not changed, our ignorance may be the cause of further instances of contamination. It is clear that many of the unanswered questions about the various chemicals and soil properties must be addressed before their safe and * effective use under different environmental conditions can be assured. By eliminating the unknowns that prevent us from understanding the problems associated with the use of chemical pesticides, we can develop effective management plans to prevent such contamination and the financial and social costs associated with it.

Industrial Chemicals

Over the last several decades, many potentially hazardous substances used by industry have regularly found their way into the environment through a combination of routine releases (e.g., effluent discharge) and unintentional releases (e.g., leaks from pipelines and spills). Although laws have been passed in recent years to control the use and disposal of toxic substances, such ***** regulation has failed to keep up with the rapid proliferation in recent decades of the development of new substances for

TABLE 1-3. GROUNDWATER CONTAMINANTS OF POSSIBLE INDUSTRIAL ORIGIN

Confirmed*
- 1,2-DCP (1,2-dichloropropane)
- Bromodichloromethane
- Bromoform
- Carbon Tetrachloride
- Chloroform
- Dibromochloromethane
- 1,2-DCE (1,2-dichloroethylene)
- Diethylphthalate
- EDB (ethylene dibromide)
- PCE (tetrachloroethylene)
- TCE (trichloroethylene)
- TCP (1,2,3-trichloropropane)

Not Strictly Confirmed, but Assumed Reliable*
- Benzene
- Freon
- Freon II
- Toluene
- Xylene
- 1,1,2-TCP
- 1,2,2-TCP
- Phenol
- Dichloropropenes
  (2,3-dichloro-l-propene) or (1,2-dichloro-l-propene)

Unconfirmed*
- Dichlorobenzene
- Ethylbenzene
- Methyl Chloride
- Methylene Chloride
- Trichlorofluoromethane

*Confirmed contaminants are those which have been explicitly confirmed with a confirmation test or which have been found at a site where the contaminants have been previously found. Other contaminants have in many areas been detected but have not had confirmation tests performed and thus are not strictly confirmed. Sources: Lau 1991; DOH 1990; DOH 1989b; DOA 1989.

industrial usage, resulting in relatively unfettered use of these new chemicals.

Moreover, enactment of regulations governing the use and handling of specific substances has not necessarily meant that those substance, no longer enter groundwater, but at best, that they enter groundwater at reduced rates. Indeed, it is probably more likely that, due to the cumulative effects of regulatory and enforcement deficiencies, rapid industrial growth, and the unprecedented rate development and use of new chemicals, the opportunities for groundwater contamination are only increasing with time. It follows from this that the magnitude of groundwater contamination from industrial sources may also be on the rise. !!

There have been twenty-one contaminants found in Hawaiian groundwater that are thought to be of industrial origin. Twelve of these findings have been confirmed and nine, while not yet strictly confirmed, are considered reliable. The presence of an additional five contaminants was not confirmed. Table 1-3 above lists these contaminants.

Unfortunately, available information on the specific likely sources of these contaminants is extremely limited. However, several plausible inferences can be made. The presence of four of the substances collectively referred to as trihalomethanes is very likely the result of the chlorination process used to treat water for municipal supply. And in at least one cause, the occurrence of ethylene dibromide (EDB) appears to be related to a series of releases of petroleum products from a military oil pipeline. The rest appear to stem from assorted industrial or military activities.

Petroleum, Oil, and Lubricant Pipeline

The U.S. military has for many years operated a petroleum, oil, and lubricant (POL) pipeline between Pearl Harbor and the Wheeler Air Force Base area near Wahiawa on O'ahu. An extensive series of leaks from this pipeline has resulted in what appears to * be one of the most serious localized groundwater contamination problems in all of Hawai'i. In the period from 1951 through 1978, there were ten reported leaks from the pipeline, totaling over 600,000 gallons of gasoline and jet fuel. The fuels transported-and thus, leaked-by the POL pipeline contained many additives, including lead and EDB (DOH, 1990a). The known leaks, the years they occurred, and the products and quantities leaked from the POL pipeline are listed in Table 1-4.

Due to the cumulative effects of regulatory and enforcement deficiencies, rapid industrial growth, and the unprecedented rate of development and use of new chemicals, the opportunities for groundwater contamination are only increasing with time. **!!

TABLE 1-4. KNOWN MILITARY POL PIPELINE LEAKS

Year	Approximate Loss	Petroleum Item
1951	10,000 gal	Gasoline
1954	70,000 gal	Gasoline
1954	20,000 gal	Gasoline
1954	86,000 gal	Gasoline
1954	300,000 gal	Gasoline
1954	20,000 gal	Gasoline
1954	22,000 gal	Gasoline
1955	15,000 gal	Gasoline
1957-58	15,000 gal	Gasoline
1978	50,000 gal	JP-4 (jet fuel)

Source: Lau, 1987.

Although apparently no specific studies have been undertaken to trace the effects of the spills on underlying groundwater, the localized EDB contamination of wells in the Waipahu area is suspected to be from the POL pipeline (Lau 1987), possibly in conjunction with some of Dole's agricultural activities in the area. As discussed in the previous action, EDB has been used extensively as a soil fumigant in Hawai'i's pineapple fields, and some of these fields are adjacent to the POL pipeline. However, based on the localized nature of the EDB contamination in the area, the expected flow directions from the pineapple fields, and the times during which EDB was apparently applied to fields, it seems unlikely that agricultural uses were primarily responsible for the EDB contamination in the Waipahu area. In fact, soil borings in a Dole field near Waipahu showed no evidence of EDB residues, in contrast to the higher rainfall mauka areas (Peterson, et al., 1985).

Chevron USA's Oil Refinery Complex

Chevron USA operates an oil refinery facility in the Campbell Industrial Park, which is located near the Barbers Point Deep Draft Harbor in Honolulu's Ewa District. In February and May 1987, the Hazardous Waste Ground-Water Task Force of the United States Environmental Protection Agency (EPA), in accordance with the requirements of the Resource Conservation and Recovery Act (RCRA), evaluated Chevron's groundwater monitoring program and data collection and record-keeping activities for three hazardous waste treatment and storage facilities they operate on the refinery site. The Task Force also conducted field analyses in an effort to determine whether there was any evidence of groundwater contamination from the facility.

*! The EPA investigation report presents a picture strongly suggestive of a serious problem with respect to Chevron's past performance and current ability to protect the quality of nearby groundwater supplies. Not only were there numerous documented instances of groundwater contamination associated with the refinery complex, but the whole of Chevron's groundwater monitoring program was found to be seriously deficient. Ironically, Chevron's groundwater monitoring efforts were so deficient that the EPA was unable to adequately assess the magnitude of the contamination problem, since the data provided by Chevron were full of gaps and often methodologically flawed.

A partial list of the many flaws identified by the EPA follows:

* ▪ Chevron failed to adequately characterize the aquifer system beneath its refinery before installing its monitoring wells; some of the key parameters not developed by Chevron before the wells were installed were groundwater flow paths, solute transport mechanisms, and subsurface geologic conditions. Without such information, samples from the wells can be expected to underestimate the true extent of any contamination.

* ▪ Despite the known presence of organic contaminants in the groundwater beneath the refinery, Chevron failed to implement a groundwater assessment program.

* ▪ While storage tanks containing crude and refined products were found to have leaked, Chevron failed to collect sufficient data to document the extent of any groundwater contamination, nor did it attempt to gauge the rate and extent of the migration of leaked substances.

* ▪ In several cases, groundwater monitoring wells had not been installed where RCRA expressly required them.

- The background monitoring well was inadequate for the purpose of establishing the baseline groundwater quality. In some cases, monitoring wells were set too far away to properly detect releases. In other cases, the wells were improperly designed.

- Chevron's sampling and analysis procedures failed to address many of the most basic elements necessary to ensure sampling consistency and quality control. The EPA report concluded that Chevron's sampling plan "was woefully inadequate as a guidance document for the Chevron sampling effort." The EPA noted further that Chevron even failed on occasion to follow its own procedures, inadequate as they were. !!!

- Chevron's waste disposal facilities had not been designed to prevent fluid migration into the groundwater; individual units were unlined and excavated into extremely permeable coralline rock not more than five feet from the groundwater. !!!

- Basic hydrogeologic and geologic research vital to the proper design of groundwater protection and monitoring facilities was evidently either done poorly or not done at all. !!!!!

In short, the EPA investigation found that Chevron's groundwater protection efforts and monitoring program were seriously inadequate and in violation of numerous provisions of RCRA. *!!! Unfortunately, due precisely to these problems of poor design and management, including improper placement and design of monitoring wells, it is presently not possible to characterize with any confidence the full extent of the groundwater contamination problem stemming from the Chevron facility. Chevron's physical monitoring system was simply not designed, installed, and managed in a way that enabled the EPA to accurately represent the magnitude of groundwater contamination being caused by Chevron's facilities. In view of this limitation, it is prudent to regard what is known about the apparent extent of any groundwater contamination as, at best, a lower bound of the true extent of the contamination problem. !!!!

What is known about groundwater contamination at the site stems from EPA file data supplied by Chevron prior to the investigation, and from the investigation itself, during which a limited set of field analyses were conducted. The file data indicate that chromium, arsenic, and lead were all detected at levels above those permitted by primary drinking water standards. **** Chromium and lead were found in concentrations exceeding the standards in four and seven of the wells tested, respectively, while arsenic levels exceeded the standards in one case.

Testing for priority pollutants was done at five wells in 1984-85. Two of these wells tested positive for various organic volatiles (e.g., benzene and toluene), one semi-volatile (napthalene), and various semi-quantified compounds, although the levels detected were not specified. ****

The limited sampling done by the EPA during its 1987 investigation revealed the same general pattern of contamination. **** Chromium and arsenic levels above primary drinking water standards were again found. Benzene, toluene, volatile and semi-volatile pollutants were all detected, once again without their levels being specified.

The investigation also revealed the presence of oil in five of the wells tested, and organic vapors in fifteen. The investigation also revealed that a layer of petroleum !!!!

was floating on the water table, and storage tanks containing crude and refined products were found to have been leaking. The constituents found were all common to refinery operations and/or their waste streams.

Two broad sets of concern arise from the situation uncovered by the EPA's investigation. The first concerns the Chevron operation itself. The EPA Hazardous Waste Ground-Water Task Force report clearly suggests an inadequate commitment on the part of Chevron to monitor and protect groundwater quality. In numerous instances, the company appears not to have taken even the most elementary precautionary measures to protect Hawai'i's groundwater from chemica1 contamination, and its monitoring and reporting efforts were so deficient that one cannot estimate with any degree of confidence how much more extensive the problem may be. Extensive redesign and revamping of the monitoring system will have to be done before the public can know the true magnitude of the contamination problem.

The second set of concerns goes beyond the particular situation at the Chevron facility, and is arguably even more worrisome. The patterns of contamination and mismanagement of hazardous materials and wastes cannot safely be assumed to be confined to the Chevron facility alone. The EPA did not choose to investigate the Chevron refinery because it was among the worst such facilities; rather, it was selected as part of a representative nationwide sample. And while it would perhaps provide a small measure of comfort to believe that Chevron is among the worst offenders in Hawai'i in the management of hazardous material and wastes, there appears to be no reason a prior to believe that this is the case.

Hawai'i has a total of twenty-nine hazardous waste treatment and storage facilities, several of which are comparable in size to Chevron's. There are also one hundred hazardous material and hazardous waste transporters presently operating in Hawai'i, and over five hundred facilities known to be generators of hazardous wastes. None of these has yet been subjected to the type of investigation that the Chevron facility received in 1987. The potential for groundwater contamination from these facilities is discussed further in Chapter 2.

Hence, while we know too little about the extent of groundwater contamination and associated potential health risk associated with the Chevron refinery, we know much less about the collective risk posed by all of Hawai'i's hazardous waste facilities. The fact that the Chevron investigation uncovered as many glaring problems as it did, and the fact that we are still a long way from knowing the full extent of the groundwater contamination problem there, make it at least reasonable to assume that Hawai'i faces a significantly greater potential groundwater contamination problem from its hazardous waste treatment, storage, and generating facilities than is yet appreciated.

Conclusions

The use of toxic and hazardous chemicals in industry and their direct and indirect releases into the groundwater were both widespread in the U.S. long before the possible health implications of these practices were adequately appreciated. In Hawai'i, which is so heavily dependent on groundwater for supplying its drinking water, the widespread nature of these practices is of even greater concern than it might be- elsewhere in the U.S. The contamination that has thus far been detected in Hawai'i from industrial sources is clearly worrisome. Even more worrisome is that the state has only begun the job of documenting the actual extent of industrial contamination and of tying it to its specific sources. Without this needed understanding, it is impossible either to say how extensive the problem may be or to know how best to prevent and mitigate it. What we do know, and what we can say, however, is that current efforts to monitor, control, and prevent contamination from industrial sources in Hawai'i are clearly inadequate. We need to know far more than we do in order to properly assess the size of any public health hazard posed by industrial contamination of Hawaiian groundwaters, and to take action to eliminate this hazard. **!!

There's more . . . please keep going . . .

There's more . . . please keep going . . .

Chapter 2: Probable, Possible, and Potential Sources of Groundwater Contamination in Hawai`i

The preceding chapter summarized the state of our knowledge regarding confirmed groundwater contaminants in Hawai'i and their likely sources. In this chapter, we turn to the more speculative task of evaluating the potential for existing or future groundwater contamination from sources for which no conclusive data yet exist. Given the paucity of data, the discussion below is necessarily limited to a fairly cursory overview of the kinds of activities and facilities that either now or in the future may be responsible for contaminating the groundwater, the contaminants that may be involved for each activity, and the apparent level of regulatory attention each is receiving. The sources considered are underground injection wells, waste oil dumping, surface impoundments, hazardous waste management, landfills, and land-use conversion from agriculture to residential. As we shall see below, there is reason to suspect that the integrity of Hawai'i's drinking water supplies faces a multitude of threats.

Injection Wells

Underground injection is a method of waste disposal whereby waste liquids are pumped through a well from the surface to a receiving aquifer. This method of waste disposal was apparently first proposed in 1966 (Burbank, 1966) at the Waimanalo Sewage Treatment Plant, as an alternative to the increasingly expensive practice of ocean outfall dumping. Since then, underground injection of wastes has become a widespread practice in Hawai'i. DOH estimates that there are on the order of one thousand operating wells presently injecting a wide variety of waste fluids into Hawai'i's aquifers. These include fluids from facilities, which generate and manage hazardous materials and wastes, including radioactive wastes; industrial and municipal waste facilities; sewage operations; and oil and natural gas production processes.

No study has yet been done to determine what kinds and quantities of contaminants are being injected into Hawai'i's aquifers. Absent such studies it is difficult to say what the magnitude of the problem may be, and impossible to say there is not a problem. Indeed, NRDC is concerned that Hawai'i's practice of disposing of wastes by injecting them into groundwaters has significantly outpaced understanding of its associated hydrologic and public health implications.

* The state does have an underground injection control (UIC) program, but it is not at all clear that the program provides adequate levels of protection of Hawai'i's groundwater. In particular, we have the following concern about the rules (Hawaii Administrative Rules, Title 11, Chapter 23) governing the state's underground injection control (UIC) program.

** The rules are written in a way that almost wholly ignores the possibility that an aquifer not presently useful for supplying drinking water may, due to economic or technological developments, at some point become useful. Specifically, the section on classification of aquifers for waste injection use, Title 11-23-04(2), reads that an aquifer may be allowed to receive such wastes if. "The aquifer cannot now and *will not in the future* serve as a source of drinking water because of any of the following criteria: (A) It is situated at a depth or location which currently makes recovery of water for drinking water purposes economically or practically impractical; or (B) It is so contaminated that it would be economically or technologically impractical to render the water fit for human consumption..." (emphasis added).

Thus, the rule effectively assumes that economic and technological conditions will never change, and therefore, that an aquifer which is presently unsuitable for drinking water will always be unsuitable. ** It ignores completely the potential - which, indeed, is already coming to pass - that changed economic and technological circumstances will make a given aquifer newly valuable for drinking water (and possibly other) purposes. In doing so, it sanctions the irrevocable commitment of possible future drinking water supplies to use as a waste disposal reservoir, making any future use for drinking water highly unlikely.

* A further concern about Hawai'i's UIC program is a decision on the part of DOH allowing the use of dry wells (i.e., shallow injection wells) located above (i.e., mauka) the current geohydrologic boundary - called the Underground Injection Control Line (UIC) - for underground injection of storm water runoff. Groundwater above the UIC line is generally of drinking water quality. The residential storm water that would thus make its way to underground sources of drinking water would inevitably carry with it pesticide and fertilizer residues from residential lawns and gardens, as well as accumulated road grease, motor oil, gasoline, and a host of other substances. Further, * and perhaps most importantly, wastes inadvertently or intentionally dumped into storm drains by local residents would also make their way into groundwater. Used motor oil, paints, solvents, acidic wash water from the cleaning of swimming pools, and detergents and solvents from home car washing are just a few of the substances that would regularly find their way into groundwater should this practice be allowed.

While dry wells were allowed previously, a permit was required for their operation. Presently no * permit is required if DOH determines "non-impact" (DOFI, pers. comm.). The apparent impetus behind this change is that DOH is presently overburdened with permit applications for underground waste injections; they believe that contamination of shallow wells with residential storm water poses fewer problems than other kinds of underground waste injection; and they are attempting to allocate their limited resources to the more important UIC permit applications. At least two concerns become evident here. The first is that while DOH's change to its UIC permit ** requirements may be an understandable administrative response to immediate staff and budget constraints, it is difficult to justify in public health terms. The second concern is that the apparent high rate of UIC permit applications being filed at DOH suggests that, however serious the overall contamination problem from underground waste injection may be, it appears to be growing steadily worse. *

In conclusion, underground injection of waste fluids has the potential to seriously contaminate Hawai'i's groundwater supplies. The practice grew up in an era when environmental health concerns were less visible, and when the quantitative limits of Hawai'i's groundwater resources and their vulnerability to migration of contaminants were not as well understood. Given what we now know, and given that we can expect brackish water supplies to play an increasingly important role in supplying future drinking water needs, it is important that the state begin immediately to carefully reassess what, if any, types of groundwater supplies are appropriate as sinks for what kinds of injected wastes, and to use that reassessment to evaluate the adequacy of the state's current UIC rules and program.

Underground injection of waste fluids has the potential to seriously contaminate Hawai'i's groundwater supplies. *

Waste Oil Dumping

The dumping of waste oil is another activity which could cause serious groundwater contamination. One sense of the magnitude of the problem is given by the DOH's estimate that about two million gallons of used oil are dumped each year in Hawai'i, or roughly 40 percent of the total amount of oil brought into the state (Honolulu *Advertiser /Star* Bulletin, April 28, 1991). The sources of the dumping are quite broad and dispersed. It is therefore reasonable to assume that much of this dumping is occurring over potable aquifers, and further, that potentially much of the oil is reaching them. Even without conclusive evidence linking oil dumping to groundwater contamination, it is clear that this could well turn out to be one of the most serious of Hawai'i's groundwater contamination problems. *

In August 1990, the DOH Hazard Evaluation and Emergency Response Office began a joint investigation with EPA Region 9 and the U.S. Coast Guard of various waste oil sites in Maili (on the southwest shore of O'ahu). One site, containing about 450 buried drums of waste motor oil and chlorinated hydrocarbon solvents, including TCE and TCA, were found to have actively leaking drums. Other chemicals may also have been dumped, but bio-remediation to clean up the site began before other chemicals could be identified. A plea agreement struck between DOH and a Maili waste oil hauler was apparently instrumental in locating several hundred other drums of waste oil and chemicals at other Maili sites as well as Sand Island. The recycler has agreed to be responsible for the removal of the drums at these sites. *

According to the DOH Hazard Evaluation and Emergency Response Office, this case is but an extreme example of what it has been finding on a regular basis. One to several drums of waste oil are routinely found abandoned, often along roadsides. The office generally correlates the timing of these findings with periods of gluts in the used oil market, when recyclers have difficulty finding markets for their product.* In one recent case in April 1991, an entire trailer full of drums of used motor oil was found at the intersection of highways H-1 and H-2 in Waipahu (DOH, pers. comm.). *

Chapter 342N of the Hawaii Revised Statutes regulates waste oil, prohibits oil dumping, and provides for fines of up to $10,000 for violators. Unfortunately, as with several of Hawai'i's other statutes related to groundwater protection, the administrative

* The waste oil is generally sold as fuel for operations such as sugar processing.

rules to implement the statute have yet to be approved (DOH, pers. comm.)

Surface Impoundments

Surface impoundments refer generally to settling and holding ponds that are used for a diverse set of industrial, agricultural, and municipal purposes, such as lagoons for piggeries, dairies, and slaughterhouses, and holding and settling ponds for oil refining, electric generation operations, municipal sewage oxidation, and sugarcane processing. These impoundments contain a variety of possible groundwater contaminants, including organic wastes, petroleum compounds, metals, and other assorted toxics. As of 1980, there were an estimated 300 impoundments at about 100 sites in Hawai'i (DOH, 1980).

A preliminary assessment of the potential for groundwater contamination from surface impoundments was conducted by the state in 1980. While the assessment did not find any significant instances of groundwater contamination that could be linked directly to impoundments, its findings are nonetheless cause for concern. First and foremost, the report made clear that if there *were* a contamination problem, the state would have little way of knowing: "Detection of pollutants from impoundments is not within the capabilities of existing monitoring practices. There is no site-specific routine monitoring program within the State" (DOH, 1980). Hence, the failure to detect significant contamination is hardly surprising, and is little reason to assume that no problem exists.

Absent any real data to go on, we have only circumstantial evidence upon which to assess the potential for groundwater contamination from surface impoundments. As noted above, impoundments in Hawai'i contain a variety of hazardous and toxic substances, and it has been noted throughout this report that Hawai'i's permeable soils generally increase the likelihood-relative to the situation on the mainland-that toxic and hazardous substances will reach groundwater once entering the soil. It is therefore reasonable to assume that, without adequate safeguards, surface impoundments may be a source of groundwater contamination. A DOH assessment of surface impoundments includes a number of observations that raise serious questions about the adequacy of the state's efforts with respect to providing such safeguards. Specifically, the report notes the following:

The state has no construction, operation, or maintenance requirements for surface impoundments.
1. A limited survey of impoundments revealed that some facilities were not designed, operated, or maintained in such away as to prevent leaching.
2. Containment problems were found; in some cases they were attributed to inadequate design and construction criteria, and in others to lack of coordination between programs within DOH.
3. Historically, surface impoundments located over marginal-quality groundwaters were often built without any safeguards against leaching, i.e., groundwater was knowingly allowed to be used as a waste sink based on at least a tacit belief that groundwater not suitable for drinking is not worthy of any protective effort. (DOH, 1980)

Added to these concerns is the fact that, due to the wide variety of uses of surface impoundments, their control and regulation is not centralized within a single branch of the Department of Health. The Solid and Hazardous Waste Branch, Clean Water Branch, and Wastewater Branch all have regulations of some kind with respect to surface impoundments. Not surprisingly, then, surface impoundment regulations and requirements often suffer from inconsistency. For example, depending on which agency is responsible for a given impoundment, it may or may not have to be lined, and it may or may not be allowed to operate above or below the underground injection control line (DOH, pers. comm.). From a public health standpoint, such inconsistency is worrisome. ****

While nothing conclusive can yet be said about the kind or magnitude of groundwater contamination that may be occurring, the virtual lack of monitoring, and the spotty and often inconsistent regulatory apparatus governing surface impoundments, provide little reason to be confident that hazardous and toxic substances known to be present in them are not reaching the groundwater and posing a potential health hazard. **** **** ****

Underground Storage Tanks ****

The problem of leaking underground storage tanks (UST) has been one of the driving forces behind recent federal legislation addressing the public health threats posed by hazardous materials and wastes. Contamination of groundwater is the primary environmental risk associated with leaking UST systems (ICF, 1990). In 1984, the U.S. Congress passed several amendments to the Resource Conservation and Recovery Act (RCRA), one of which (Subtitle 1) specifically addressed the problem of leaking USTS. The rationale for such legislative action with respect to USTs is very clear: the EPA estimates that of the two million underground storage tanks in the U.S., some 500,000 are presently leaking petroleum products and other hazardous substances, posing a serious threat to the nation's groundwater supplies, and by extension, to drinking water supplies and public health. Because Hawai'i depends much more heavily on groundwater than does the mainland for its drinking water, the relative threat from leaking UST, may be significantly greater here than n the mainland.

As of April, 1991, 253 of Hawai'i's 4300 registered USTs were known to be leaking (DOH, 1991).* The number of leaking tanks found to that point on each island is listed below. ***

TABLE 2-1. LEAKING UNDERGROUND STORAGE TANKS DETECTED

Island	# of Tanks	% of Total
O'ahu	200	79.1 ***
Hawai'i	22	8.7
Kaua'i	14	5.5
Maui	11	4.3
Lana'i	5	2.0
Moloka'i	1	0.4
All Islands	253	100.0

Source: DOH, 1991.

* The actual number of USTs in. Hawai'i is likely to be considerably higher, than this. A mandatory UST registration program was phased in over the past few years, but many of the o1der tanks, especially those associated with defunct businesses, may not be registered. According to DOH, there have been numerous examples in which new landowners have discovered USTs upon developing the property (*Honolulu Advertiser*, April 22, 1991).

The health risks from leaking underground storage tanks are real, potentially serious, and likely mounting. !*! * ***** ***** !!!!! !!!!!

Most of Hawai'i's USTs, however, have not yet been checked for leaks, so many more are bound to be leaking. Based on the EPA survey, which indicated that fully one fourth of all tanks nationwide may be leaking, Bruce Anderson, Deputy Director of the Hawai'i Department of Health, reportedly expects to find over the next several years at least one thousand more leaking USTs (*Honolulu Advertiser*, April 22, 1991). DOH currently receives notification of about 30 new releases per quarter and this rate is expected to increase (ICF, 1990).

Most of these tanks are located at gasoline and automobile service stations, but numerous others are located at such sites as elementary and high schools, hotels and resorts, health care facilities, public storage areas, dry-cleaning businesses, dairy facilities, chemical processing plants, fire stations, and car sales and rental businesses.

There are several reasons to believe that Hawai'i's leaking UST problem and the resulting contamination may well be even more of a problem than is suggested by a simple extrapolation from the EPA's survey data. For one, a 1990 actuarial study sponsored by DOH (ICR, 1990) found that USTs in Hawai'i are on average older than those in the mainland U.S. Not only is an older stock of tanks more prone to leaking by simple virtue of their more advanced age, but owing to considerable advances in UST technology over the years (tanks are now routinely equipped with leak detectors and anti-corrosion coatings and devices) older USTs can also be expected to leak sooner in their lifetimes than newer USTS.

While there is not yet any hard evidence linking UST leaks with groundwater contamination, the confluence of factors cited above suggest there is good reason to be seriously concerned about the possibilities that past leakages may have already contaminated groundwaters, and that present and future leakages my result in further contamination. Hawai'i's unique hydrogeology, the large number of leaking tanks; and their broad distribution throughout Hawai'i, the fact that many of them are located over presently used potable water supplies, together make it quite likely that USTs are responsible for, fairly widespread and significant amounts of groundwater contamination. Indeed, based on available data, DOH estimates that *75-90% of releases from USTs find their way* into groundwater (ICF, 1990).

Unfortunately, the issue of leaking USTs has only recently been addressed by the State of Hawai'i. Chapter 342L, Hawai'i Revised Statutes (1990 Supplement), specifically deals with USTS, but administrative rules to implement the statute - i.e., to develop an actual underground storage tank regulation program - have yet to be approved (DOH, pers. comm.). Until such rules are approved, federal regulations (40 CFR Parts 280 and 281) promulgated by the EPA in 1988 will apply. However, these federal regulations are not intended to substitute for state regulation, nor is it realistic to assume that the EPA is capable of providing adequate regulatory oversight for the thousands of USTs in Hawai'i. A state program is urgently needed.

Powerful evidence of the need for a strong state UST program is provided by a 1990 DOH survey of UST owners and operators which revealed that about one-fourth of the respondents had difficulty obtaining the necessary financial coverage to meet federal regulations (ICF, 1990). One of the sections of Chapter 342L provides for the establishment of a "financial responsibility guarantee fund," which was intended as an interim measure to address this very problem. Unfortunately, not only has this program not yet been established, but the State Legislature passed an amendment during the 1991 legislative session weakening this statute by removing the guarantee feature of the fund. In conclusion, the health risks from leaking USTs are real, ***** potentially serious, and likely mounting. A comprehensive state management program is sorely and urgently needed, and a financial assurance fund for cleanup efforts is an essential part of such a program, to at least moderate the health risks posed by currently leaking tanks.

Hazardous Waste Management

Like the problem of leaking USTS, hazardous materials and waste facilities, have been the subject of major federal environmental legislation (primarily the Resource Conservation and Recovery Act, or RCRA) and a major priority of the EPA's regulatory efforts. Unfortunately, this emphasis has not yet led to any appreciable diminishment of the public health risks from hazardous wastes, either on the mainland or in Hawai'i. *****

Hawai'i does not yet have its own hazardous waste regulations, but is in the process of developing them (DOH, pers. comm.). Instead, EPA regulations pursuant to RCRA Subtitle C “Hazardous Waste Management” are applicable. As of November, 1990, Hawai'i had a total of 699 hazardous materials and waste facilities listed in the state's RCRA Database (DOH, 1990b) These facilities are grouped into three classes: treatment, storage, and disposal facilities* (TSD); transporters; and generators. Most of these facilities are located on O’ahu, although the proportion (70%) is somewhat lower than one would expect based on population distribution. Table 2-2 lists these facilities by group, showing totals both for the state as a whole and for O’ahu specifically.

TABLE 2-2. HAZARDOUS WASTE FACILITIES AND GENERATORS IN HAWAI’I*

	O’ahu	State Total
Treatment and Storage Facilities	**22**	**29**
Transporters	**71**	**100**
Generators		
- Over 1,000 kg. of non-acutely hazardous waste or 1 kg. of acutely hazardous waste per year	**142**	**203**
- Between 100 kg. and 1,000 kg. of non-acutely hazardous waste per year	**240**	**338**
- Less than 100 kg. of non-acutely hazardous waste per year	**14**	**29**

*** Includes all facilities that have notified the state or filed a permit application that was pending as of November 9, 1990.**

Source: DOH 1990b.

Reports of groundwater contamination from hazardous waste facilities appear to be limited to those associated with the Chevron refinery near Barbers Point; these were discussed in Chapter 1. As mentioned in that earlier discussion, a broad pattern of

* Hawai’i state law prohibits in-state disposal of hazardous wastes, so they are currently shipped elsewhere for disposal. Effectively, then, this category encompasses only treatment and storage facilities.

neglect with respect to responsible monitoring and management was discerned by the EPA in its investigation of the Chevron refinery in the Barbers Point area. If any significant part of this pattern should apply also to Hawai'i's other hazardous materials and waste facilities, transporters, and generators, there could well be significant groundwater contamination implications. Organic industrial chemicals of the sort that are handled by these industries have certainly been found in Hawai'i's groundwater, but because existing monitoring programs are generally inadequate, it is not possible to attribute them to any specific source. Unfortunately, too little is yet known to do much more than speculate about the true size of any groundwater contamination problem associated with the state's hundreds of hazardous waste facilities and generators. More information is urgently needed to better understand the groundwater contamination risk that may be posed by these facilities.

Landfills

Leaching from either closed or operating landfills is another potentially significant source of groundwater contamination. Landfills receive a wide variety of materials, many of which contain toxic or hazardous contaminants; it is possible that these contaminants may leach through the soil to underlying aquifers. Heightening this concern is the fact that, as presently written, the State's Administrative Rules governing solid waste management (Title 11, Chapter 58), which were last approved in 1981, actually permit the dumping of hazardous wastes into landfills, a practice that is now illegal.*

Study of the groundwater contamination potential from landfill leachate has been extremely limited. Only two reports are available on this issue: on laboratory-based simulation study (Chun, et al., 1975), and one field study on the effects of the Kapa'a Landfill on the Kawainui marsh (Chun and Dugan, 1981). The first study, which considered five different types of soil found on O'ahu, established that it is clearly possible for organic and inorganic substances to migrate through the soil profiles to underlying groundwater. Unfortunately, the substances tested were limited to standard, legally disposable household and construction wastes. As such, it did not include substances, such as used motor oil or spent lead-acid from batteries, which are almost assuredly part of typical landfill composition even though they are not supposed to be disposed of in normal landfills.

The second study entailed monitoring six wells for various parameters that might indicate that landfill leachate from the Kapa'a landfill was leaking into groundwaters and marsh waters of the Kawainui Marsh. No evidence of contamination was found in that particular case. The authors did, however, see a need for regular monitoring of the sites, and proposed a minimum monitoring program schedule. Clearly, a more extensive monitoring program for all of Hawai'i's landfills is needed to determine their level of threat to the groundwater.

Conversion from Large-Scale Agriculture to Residential Development

As more and more large-scale agriculture is displaced by residential development, further groundwater contamination may result. Oki, et al. (1990) suggest that because of the relative lack of effective control on household, lawn, and garden pesticide use, further groundwater contamination from residential sources is possible. The difficulty of managing pesticide use in residential areas results from several fac-

* DOH claims that these rules have been re-written to reflect current solid waste management laws and are currently under review by county and other state agencies (DOH, pers. comm.) .

tors. Home owners are likely to have less experience and be less informed about which pesticide to use, the proper quantities and frequencies to use, the effects of pesticide use, and proper pesticide disposal. Oki, et al. recommended that use of highly persistent and mobile pesticides, such as bromacil and atrazine, be restricted in residential areas to reduce the potential for groundwater contamination.

As discussed in the preceding section, the proposed use of dry wells for storm water disposal from residential areas located over drinking water aquifers would likely result in additional groundwater contamination as well. Increasing land-use pressures to convert from large-scale agriculture to residential developments would only exacerbate this situation. The state needs to pay increasing attention to the groundwater contamination risk posed by this and other changing land use practices.

Conclusions

In Chapter I it was suggested that the known extent of groundwater contamination is but the "tip of the iceberg" of a problem whose actual dimensions are as yet largely unknown. In this chapter, we have provided circumstantial evidence that suggests strongly that the actual contamination problem is very likely significantly more serious than is yet evident from simply noting contamination levels detected in drinking water wells to date. Indeed, it is conceivable that the sources considered in this chapter pose an even greater public health risk than do the sources considered in Chapter 1. At the very least, they add significantly to the overall concerns over groundwater contamination and its associated public health concerns. In any case, it is premature to focus regulatory resources and attention on any particular set of contamination sources simply because better data happen to have been collected for one source rather than another. Instead, regulators and legislators should make as a central feature of future efforts the compilation of high quality data for all of the contamination sources, which have at least a reasonable potential for contaminating groundwater and posing a public health hazard. **

There's more . . . please keep going . . .

There's more . . . please keep going . . .

Chapter 3: Hawai`i's Groundwater Protection Strategy

In recognition of Hawai'i's heavy dependence on groundwater, and in response to federal and state statutes, the Hawai'i Department of Health (DOH) has prepared an official groundwater protection strategy. The adopted strategy contains many useful proposals for actions that could be taken to protect Hawai'i's groundwater. Unfortunately, though, the adopted strategy is better characterized as a strategy to develop a strategy, rather than a strategy to implement measures that will actually protect Hawai'i's drinking water supplies. Given what we know about the groundwater pollution that has already occurred in Hawai'i and the potential for future contamination, the lack of an active state implementation strategy is disturbing. In this chapter, we summarize the key elements of the current strategy, analyze its strengths and deficiencies, and identify the changes needed in order to establish a strong and effective groundwater protection program for Hawai'i.

Description of the Groundwater Protection Strategy

The Hawai'i Groundwater Quality Protection Strategy (hereinafter "DOH Protection Strategy" or "Strategy') was issued by DOH in March of 1990 after nearly a decade of preparation (marked by stops and starts caused by gaps in funding) (DOH, 1990). It was subsequently adopted by the Governor as the official state strategy. Preparation of the strategy was mandated and funded by the Hawai'i Legislature in Act 220-86, and serves as one of the elements of the state's Water Quality Plan, required under the State Water Code passed by the Legislature in Act 45-87 (DOH, 1990). Like many other states, Hawai'i was additionally encouraged to develop a groundwater protection program under Section 106 of the federal Clean Water Act, which authorizes the U.S. Environmental Protection Agency (EPA) to provide funds to states with protection programs. Hawai'i received $157,000 from the EPA in 1991 under this program (pers. comm., Doris Betuel, EPA).

The DOH Protection Strategy provides a good overview of the importance of protecting Hawai'i's groundwater and the difficulties inherent in achieving this goal.

The Strategy contains a clear statement of its purpose and goal, and describes the policy which DOH intends to follow in order to make groundwater protection a manageable task. The Strategy includes useful chapters with explanatory information regarding the value of the groundwater resource to Hawai'i and the mechanisms by which groundwater pollution can occur. It also contains maps summarizing the reported incidents of contamination that have occurred thus far on each of the islands. The Strategy describes the monitoring efforts to date, and the plans to develop an expanded monitoring program. It contains a list of preventive measures that DOH may eventually consider adopting. Finally, it has a workplan for the years 1989-1993.

Compared to many government policy documents, the DOH Protection Strategy is refreshingly honest about its purpose and limitations. The introduction states those limitations explicitly, acknowledging that the DOH Protection Strategy does not itself represent a comprehensive protection program, but rather that the development of such a program will be a “long-term process” (DOH, 1990, p. 1-3). The introduction also emphasizes that "New laws and regulations are also needed to protect groundwater' (DOH, 1990, p. 1-4). Thus, DOH has anticipated in the document itself perhaps our strongest criticism of its Protection Strategy, namely the fact that, despite its title, the Hawaii Groundwater Quality Protection Strategy is *not* a protection strategy. Rather, it is a “workplan to develop,” among other things, “[a] state-wide program to protect groundwater resources, [a] shorter-term action plan and strategy for dealing with groundwater quality problems," and “long-term plans for resource, protection" (DOH, 1990, p. 11-1).

Given the fact that the initial awareness of the vulnerability of Hawai'i's groundwater to contamination occurred some ten years ago, we are concerned that Hawai'i's protection strategy is still at this early stage of development. While we understand that some progress has been made in the last few years on the activities proscribed in the adopted strategy, the current Strategy does not include any schedule or process for the development of real protective measures, as will be discussed at greater length below.

Key Issues of Concern

NRDC is concerned about five general aspects of the adopted Strategy: (1) the adequacy of current monitoring efforts; (2) the superficial and misleading discussion of reported contaminants; (3) the lack of a clear plan to develop protective measures; (4) its ambiguous goal with respect to the protection of currently unpolluted groundwater; and (5) the lack of an effective public participation program. Each of these concerns is elaborated below.

Adequacy of Monitoring Program

In light of the fact that serious contamination of Hawai'i's groundwater was first observed a decade ago, we would expect that by now the state of Hawai’i’ would have developed an extensive monitoring system to detect any other hints of contamination before they become major remedial problems. Unfortunately, the present monitoring system can at best be considered only a beginning effort, and falls substantially short of the level needed to enable Hawai'i citizens to feel secure about their drinking water supplies.

To its credit, the DOH Protection Strategy lays out many of the shortcomings of the existing monitoring system: “The present groundwater monitoring system in Hawaii is not designed to demonstrate cause and effect relationships between pollution sources and changes in groundwater quality." (DOH, 1990, p. X-1). The main problem with the current system is that most of the data are from drinking water wells, which are ironically not the best source of information about the condition of the groundwater resource. ****

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While it is essential to maintain information about the quality of water supplied from drinking water wells, the wells themselves are not reliable barometers of groundwater pollution for several reasons. First, in most instances, drinking water wells have not historically been located near pollution sources. Thus, contamination may be occurring or have already occurred years or even decades ago - but if it has not migrated to the area from which the well draws, it will not be detected by monitoring of the drinking water supply. As is stated in the DOH Protection Strategy, "There are only a few site-specific observation wells throughout the State where the monitoring of water around potential contamination sources can actually occur: *therefore it is currently impossible to adequately assess and evaluate the impacts of these contaminant sources on* groundwater *quality"* (DOH, 1990, p. X-1, emphasis added). *****

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The second reason that drinking water wells are not suitable monitoring posts is that they often do not provide a sample from the level within the aquifer most likely to allow early detection of pollution. Most wells draw from deep within rather than at the top of an aquifer, where pollution from surface sources is most likely to occur first. Thus, an extensive network of new monitoring wells is needed in order to allow Hawai'i to develop a protective, rather than reactive, groundwater strategy. ****

The DOH Protection Strategy lays out a two-staged response to the need to expand monitoring efforts, beginning with an interim monitoring strategy, which has been mostly completed, and following with the development of a long-term strategy. The monitoring that occurred over the last few years under the interim strategy was very limited: as of 1989 only 33 samples were taken (DOH, 1990). While the number of wells currently being sampled has risen to between fifty and seventy, this is still a small fraction of the 430 municipal and domestic wells in the state (DOH, 1990). In addition, over 75 percent of these samples are still being taken from drinking water wells (pers. comm., Dan Chang, DOH). Part of the problem may derive from the fact that the monitoring program is run by DOH's Drinking Water Section rather than the Groundwater Section. As a result, there appears to be a continuing excessive reliance on results from drinking water wells. ****

While NRDC does not dispute the importance of an active drinking water monitoring program, it is imperative that a much more extensive sampling program be established immediately, relying on other existing wells such as irrigation wells, and developing new sampling points at strategic locations. The purpose of this expanded monitoring effort would be to identify emerging trends throughout the groundwater resource in an effort to reduce the threat of further contamination. Such monitoring must also be distinguished from drinking water monitoring in that it should use techniques and equipment capable of detecting contaminants at much lower concentrations than are typically the basis of concern in drinking water. For example, if the maximum contaminant level for DBCP is 0.2 ppb and a sample is analyzed only to determine whether the substance is found in a concentration greater than or equal to that level, the monitoring may fail to detect the substance's presence. Thus, an opportunity to conduct detective or preventive monitoring, which would contribute to an understanding of water quality trends, will have been missed. ****

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A full-scale trend monitoring effort would of course be more costly than the current level of sampling, perhaps on the order of $500,000 per year. Given the current state budgetary situation, we recognize the difficulty of funding an expanded monitoring effort. However, compared to the cost of installing water treatment equipment retroactively once a problem has been discovered too late, such an investment appears to be a bargain. We believe that the investment could be made affordable if it were shared among several agencies, as described below.

NRDC recently learned of a new groundwater monitoring program, initiated by the U.S. Geological Survey (USGS) on behalf of several of the county Boards of Water Supply, that could serve as the basis for water quality trend monitoring. The USGS has entered into a Memorandum of agreement (MOA) with the Kaua'i, Hawai'i and Honolulu Boards of Water Supply to begin a program of test drilling to determine the availability (but not quality) of groundwater. In this program, USGS will be drilling new wells that would also be good groundwater quality monitoring sites, because they are not regularly pumped, would generally be shallower than normal drinking water wells, and would therefore provide samples from depths where pollutants would most likely be first detected.

Although the USGS sampling effort is not presently intended to evaluate water quality, USGS has indicated that it would be willing to make the samples available for quality analysis. DOH has expressed an interest in entering into n MOA with USGS for this purpose, but is currently constrained by a lack of funds needed to perform the chemical analyses. DOH estimates that the evaluation would require about $125,000 in the first year to analyze the samples taken by USGS from 20 new wells on O'ahu.' DOH has requested the U.S. Environmental Protection Agency to provide the necessary funds. While EPA has indicated that it cannot provide the needed funds during the present fiscal year, we are hopeful that funds and/or laboratory support will be made available in the new fiscal year, beginning October 1, 1993. If so, this effort would represent the beginning of an important new step in safeguarding Hawai'i's drinking water supplies from future pollution problems.

Discussion of Current Findings of Contaminants

In our view, the DOH Protection Strategy does the public a great disservice in its presentation of the current findings on groundwater contamination in Hawai'i. The chapter containing this information, entitled "Groundwater/Drinking Water Summary of Reported Positive Results," consists primarily of a set of maps of each of the islands denoting the locations and detected levels of "confirmed" contaminants. While the maps themselves provide useful information, the DOH Protection Strategy is surprisingly silent on the meaning of the findings from a policy or regulatory standpoint. It is left to the reader, for example, to compare the detected levels with applicable drinking water standards (which are, fortunately, listed in tables under each map), to determine whether violations are occurring and how serious they are. By omitting any discussion of whether the findings represent any threat to public health, the DOH Protection Strategy appears to indicate that there is no reason for concern. NRDC does not believe that this is the case.

We reproduce the maps here for the reader's information, and offer the following observations on their significance. As is shown in Figure 3.1, the greatest and most serious findings of contamination are on the island of O'ahu, where twenty-eight

* **Letter from Bruce S. Anderson, Deputy Director, Hawai'i Department of Health, to John Wise, Deputy Regional Director, U.S. Environmental Protection Agency, January 5, 1993.**

incidents of contamination were found. At least nine of these are drinking water wells, which were found to contain contaminants at levels exceeding the federally adopted "maximum contaminant levels," (MCLS) or other relevant drinking water standards. (See Summary for a discussion of the meaning and usage of MCLS and other relevant drinking water standards.)

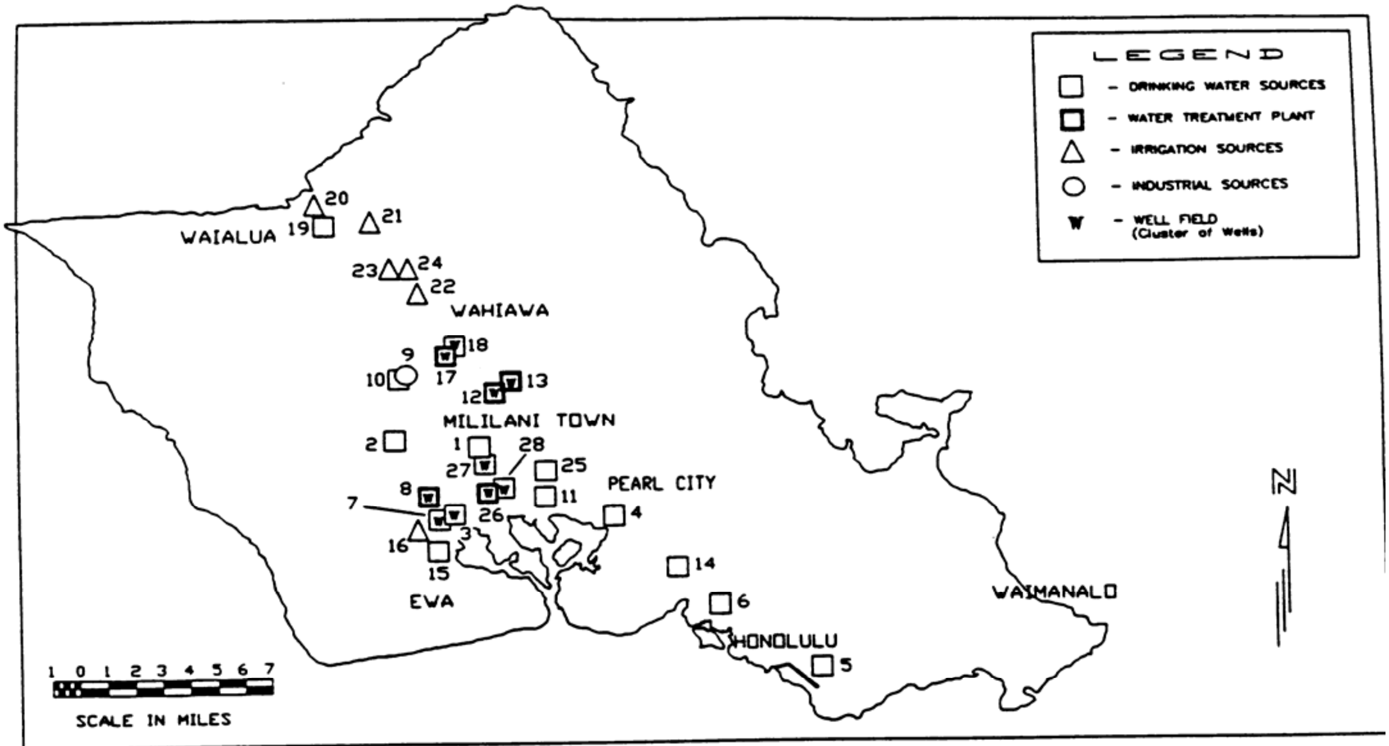
The identified contaminants include the "probable" carcinogen DBCP, at levels ten and twenty-eight times greater than the one-in-a-million cancer risk level; the "probable' carcinogen TCE at a level five times the MCL; the "probable" carcinogen dieldrin at levels four times the one-in-a-million cancer risk level (in two separate instances); the "possible" carcinogen DCE at a level three times the one-in-a-million cancer risk level; and TCP at levels two, three and four times the lifetime, health advisory level. ★

In addition, it is impossible to ascertain from the findings given for four of the O'ahu drinking water wells whether or not contaminant levels exceed applicable standards (see numbers 8, 12, 13, and 26 in Figure 3-1). This is because the level reported is given as less than a certain number, i.e., < 0.20 ppb, when the applicable standard is itself significantly less than the number given. Thus, these wells may also be supplying drinking water at levels greater than applicable standards. ★★ !!!!

The only other island reported to have confirmed contaminants at levels believed to be unsafe for drinking water (see Figure 3.2) is Maui. One drinking water well was found to be contaminated with TCP at seven times the lifetime health advisory. A second well, used for irrigation purposes, was also found to contain TCP at a level seven times the lifetime health advisory, as well as the "probable" carcinogen EDB at 167 times the one-in-a-million cancer risk level, and DBCP at 130 times the one-in-a-million cancer risk level. As can be seen from Figure 3.2, this irrigation well (number 8) is located only one mile from the contaminated drinking water well (number 7).

The islands of Hawai'i and Kaua'i had eleven and four findings, respectively, of contaminants in groundwater wells, but not at levels considered unsafe for drinking water (see Figures 3.3 and 3.4). No confirmed contaminants were found for Moloka'i and Lana'i.

FIGURE 3-1. GROUNDWATER CONTAMINATION ON THE ISLAND OF O'AHU



This Map Contains the Last Confirmed Results From Contaminated Groundwater Wells

NO.	CONTAMINANT		DETECTED LEVEL (in ppb)	APPLICABLE DRINKING WATER STANDARDS (in ppb)	
1	TCE		0.70	5.0	MCL
2	DBCP		0.01	0.0007	10^{-6}
	PCE		0.22	5.0	pMCL
3	Atrazine		0.114	3.0	LHA
	TCP		0.20	0.06	LHA
4	PCE		0.03	5.0	pMCL
5	PCE		0.03	5.0	pMCL
6	Dieldrin		0.008	0.002	10^{-6}
7	Atrazine		0.083	3.0	LHA
	TCP		0.65	0.06	LHA
8	DBCP	influent effluent	0.02 <0.02	0.0007	10^{-6}
	TCP	influent effluent	0.65 <0.20	0.06	LHA
9	PCE		1.65	5.0	pMCL
	TCE		3.70	5.0	MCL
10	Carbon Tetrachloride		0.69	5.0	MCL
	DCE		0.20	0.06	10^{-6}
	TCE		0.83	5.0	MCL
	PCE		2.60	5.0	pMCL
11	PCE		0.3	5.0	pMCL
12	DBCP	influent effluent	0.07 <0.02	0.0007	10^{-6}
	DCP	influent effluent	0.64 ---	0.6	10^{-6}
	TCP	influent effluent	1.50 <0.20	0.06	LHA
13	DBCP	influent effluent	0.07 <0.02	0.0007	10^{-6}
	DCP	influent effluent	0.74 ---	0.6	10^{-6}
	TCP	influent effluent	1.50 <0.20	0.06	LHA

NO.	CONTAMINANT		DETECTED LEVEL (in ppb)	APPLICABLE DRINKING WATER STANDARDS (in ppb)	
14	Dieldrin		0.009	0.002	10^{-6}
15	Atrazine		0.035	3.0	LHA
16	Atrazine		0.100	3.0	LHA
17	TCE	influent effluent	8.50 <1.00	5.0	MCL
	PCE	influent effluent	0.37 <1.00	5.0	pMCL
18	Carbon Tetrachloride		0.58	5.0	MCL
	PCE		0.38	5.0	pMCL
19	TCP		0.21	0.06	LHA
20	Lindane		0.001	0.03	10^{-6}
21	DBCP		0.01	0.0007	10^{-6}
	TCP		0.29	0.06	LHA
22	DBCP		0.02	0.0007	10^{-6}
	TCP		0.37	0.06	LHA
23	DBCP		0.115	0.0007	10^{-6}
24	DBCP		0.01	0.0007	10^{-6}
	TCP		0.43	0.06	LHA
25	DBCP		0.024	0.0007	10^{-6}
	TCP		0.21	0.06	LHA
26	EDB	influent effluent	0.055 <0.02	0.0004	10^{-6}
	TCP	influent effluent	<0.20 <0.20	0.06	LHA
27	TCE		0.55	5.0	MCL
	TCP		0.25	0.06	LHA
28	TCP		0.20	0.06	LHA

NOTE: Due to the number of wells in close proximity to each other, some sites are represented by wellfields and may contain several wells.
Possible natural contaminants such as nitrates have not been included.

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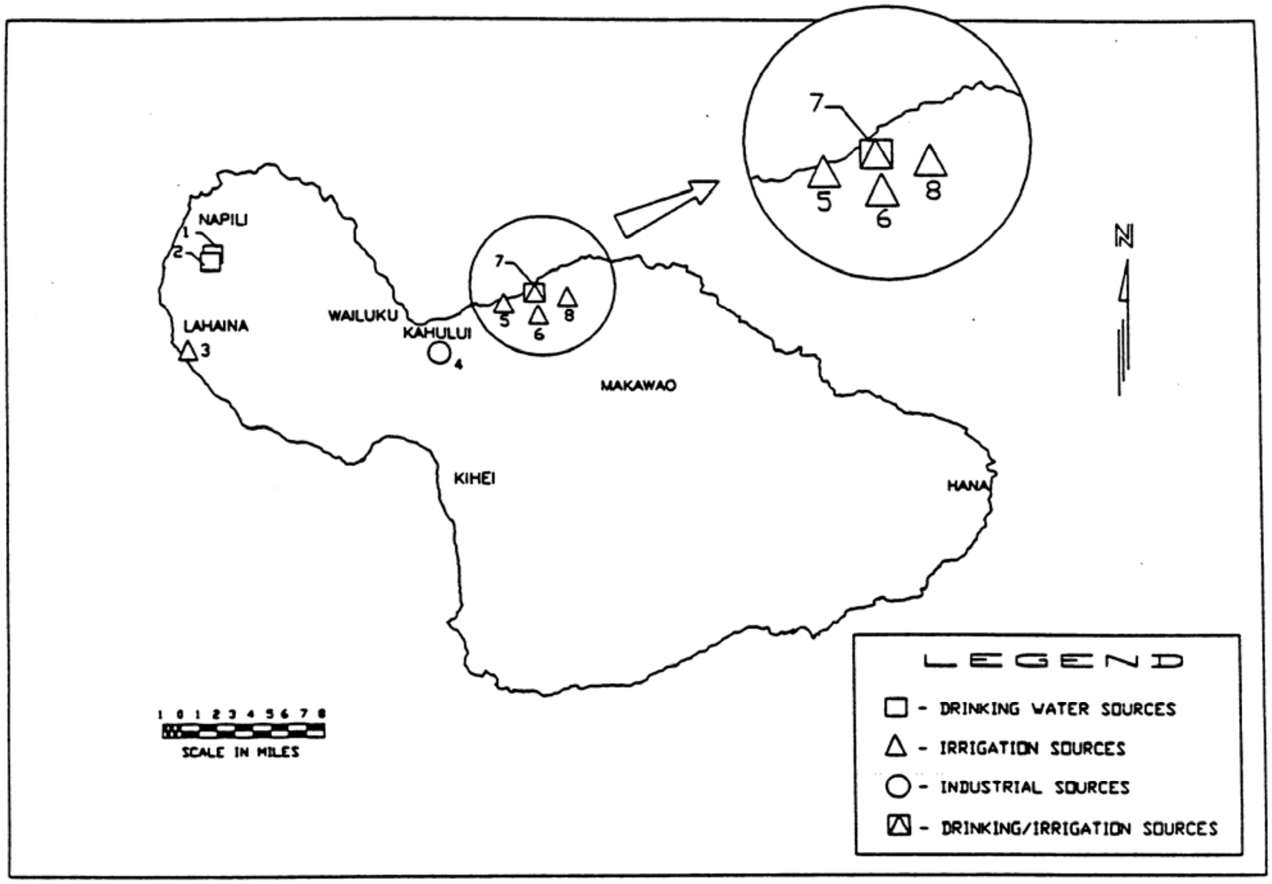
FIGURE 3.2. GROUDWATER CONTAMINATION ON THE ISLAND OF MAUI



This Map Contains the Last Confirmed Results From Contaminated Groundwater Wells

NO.	CONTAMINANT	DETECTED LEVEL (in ppb)	APPLICABLE DRINKING WATER STANDARDS (in ppb)	
1	Trichloropropane	0.200	0.06	LHA
2	Trichloropropane	0.300	0.06	LHA
3	Atrazine	0.110	3.0	LHA
4	Atrazine	1.000	3.0	LHA
	Ethylene Dibromide	0.040	0.0004	10^{-6}
5	Atrazine	0.600	3.0	LHA
6	Ethylene Dibromide	0.028	0.0004	10^{-6}
7	Trichloropropane	0.430	0.06	LHA
8	DBCP	0.091	0.0007	10^{-6}
	Ethylene Dibromide	0.067	0.0004	10^{-6}
	Trichloropropane	0.430	0.06	LHA

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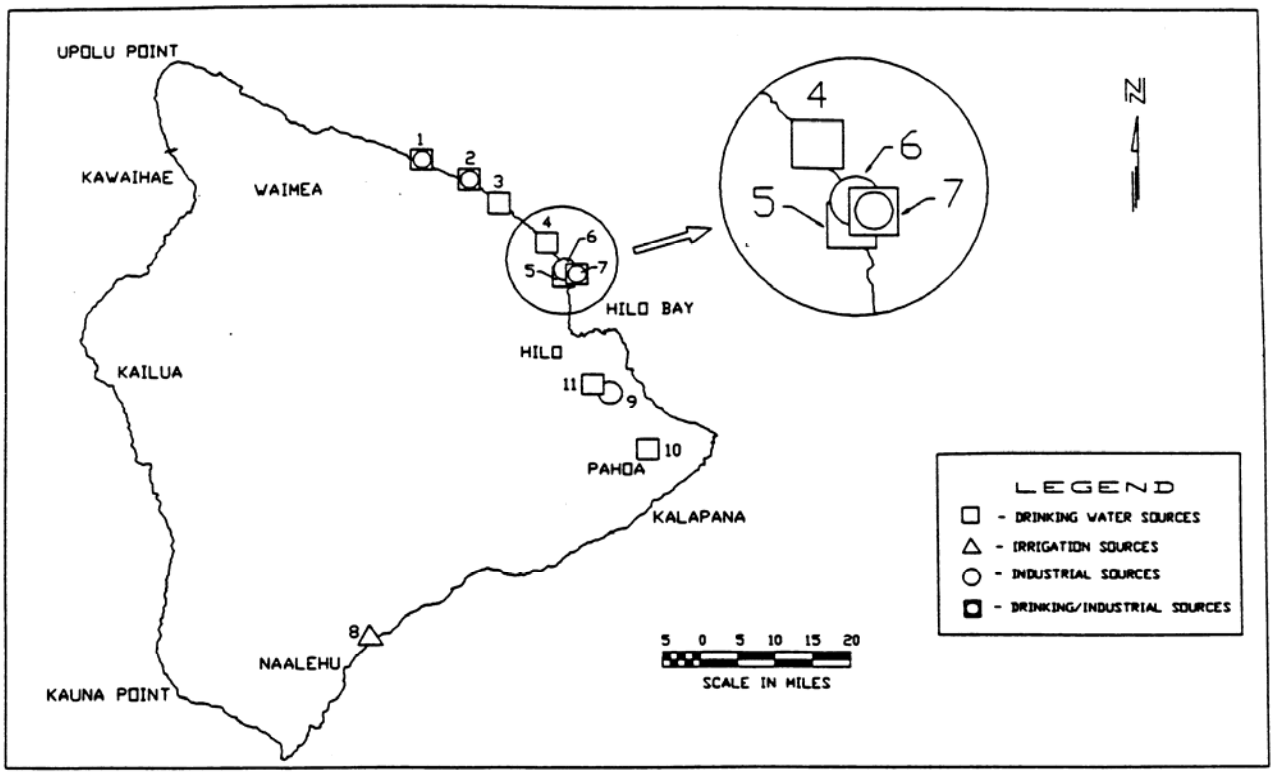
NOTE: Possible natural contaminants such as nitrates have not been included

FIGURE 3.3. GROUNDWATER CONTAMINATION ON THE ISLAND OF HAWAI'I



This Map Contains the Last Confirmed Results From Contaminated Groundwater Wells

NO.	CONTAMINANT	DETECTED LEVEL (in ppb)	APPLICABLE DRINKING WATER STANDARDS (in ppb)	
1	Atrazine	0.270	3.0	LHA
	Hexazinone	0.110	200.0	LHA
2	Atrazine	0.270	3.0	LHA
3	Atrazine	0.400	3.0	LHA
	PCE	0.130	5.0	pMCL
5	Atrazine	0.300	3.0	LHA
	Hexazinone	.0.060	200.0	LHA
6	Atrazine	0.400	3.0	LHA
	Hexazinone	0.090	200.0	LHA
7	Atrazine	1.300	3.0	LHA
	Hexazinone	0.090	200.0	LHA
8	Atrazine	0.140	3.0	LHA
9	Atrazine	0.260	3.0	LHA
	Ametryn	0.880	60.0	LHA
10	Atrazine	0.300	3.0	LHA
11	Atrazine	0.100	3.0	LHA

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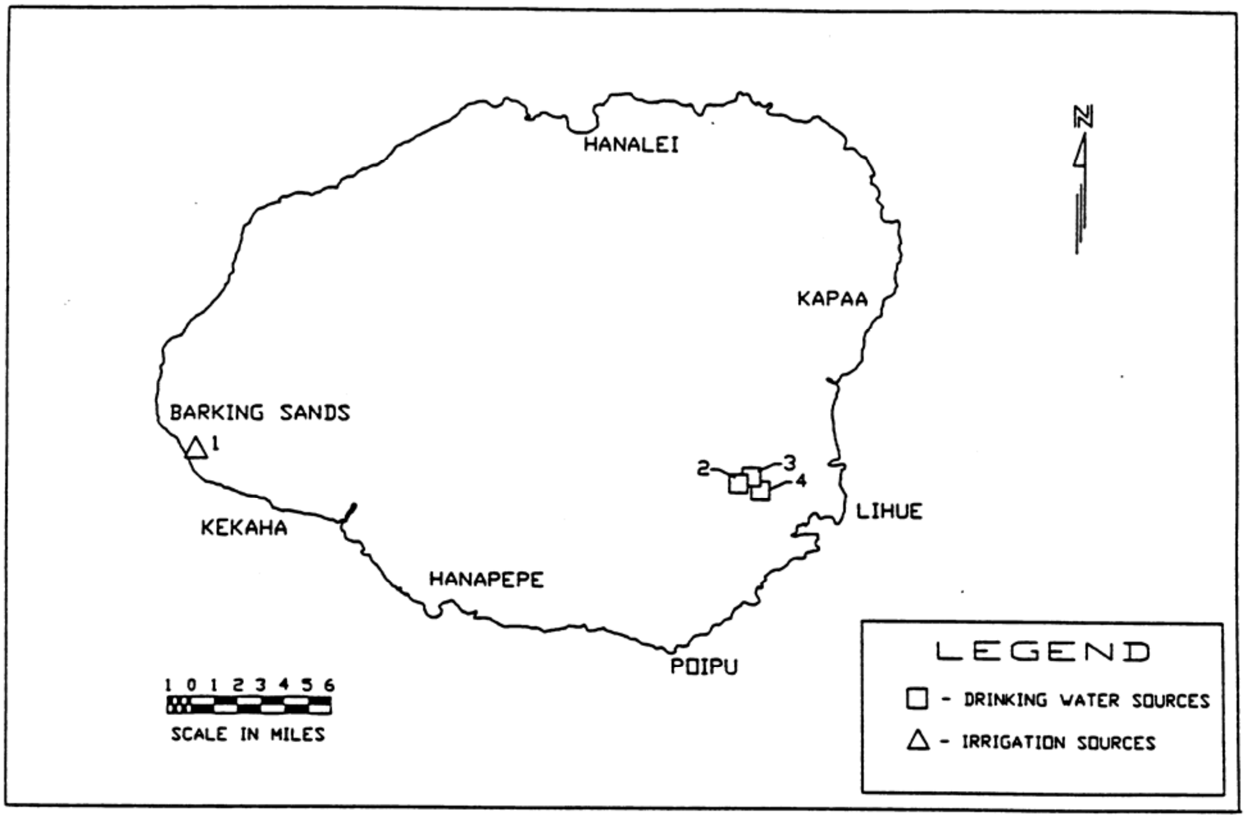
NOTE: Possible natural contaminants such as nitrates have not been included.

FIGURE 3.4. GROUNDWATER CONTAMINATION ON THE ISLAND OF KAUA'I



This Map Contains the Last Confirmed Results From Contaminated Groundwater Wells

NO.	CONTAMINANT	DETECTED LEVEL (in ppb)	APPLICABLE DRINKING WATER STANDARDS (in ppb)	
1	Atrazine	2.500	3.0	LHA
	Ametryn	0.800	60.0	LHA
	Simazine	0.200	1.4	LHA
2	Atrazine	0.060	3.0	LHA
3	Atrazine	0.200	3.0	LHA
4	Atrazine	0.100	3.0	LHA

Department of Health

May 1990

NOTE: Possible natural contaminants such as nitrates have not been included

What should we make of these findings? Taken at face value, NRDC views them as an indication of a public health problem that is relatively small in terms of its current dimensions, but one that is potentially serious in the long term. While only a handful of wells have thus far been found unsafe for drinking water, they represent a disturbing indication that what occurred with the Waipahu and Mililani wells in the early 1980's may be repeated at other drinking water wells throughout O'ahu and on the outer islands. Even more disturbing is the realization that, because Hawai'i's monitoring program is still in its infancy, we do not yet know the full extent of the problem. As described above, only a small percentage of Hawai'i's drinking water wells are yet being monitored for contamination by pesticides and industrial chemicals. As we also pointed out earlier, little monitoring is yet being conducted of the groundwater outside of drinking water wells to determine what contaminants are present in Hawai'i's aquifers and whether they are likely to move towards drinking water wells. Thus, we believe that the DOH Protection Strategy should have included some commentary to alert the public about the possible ramifications of the findings to date.

Adoption of Protective Measures

Perhaps one of our greatest criticisms of the current Protection Strategy is that, although it discusses the need to adopt actual protective measures, it fails to provide any process for assessing what measures are needed or to conduct the administrative tasks necessary for their adoption. The entire Strategy is replete with references to the need eventually to restrict activities that threaten groundwater quality. For, example, Groundwater degradation shall be prevented by restricting activities that may threaten groundwater in areas where groundwater is vulnerable to contamination, and by requiring the utilization of best practical control technology to protect the public's health and sensitive ecological systems. The burden of proof that proposed activities will riot degrade groundwater rests with the permit applicant" (DOH, 1990, p. IV-1). Similarly, in discussing the anti-degradation policy: "Monitoring and trend analysis of results shall be used to determine appropriate action to be taken where contamination of drinking water sources has resulted from current or past activities… Trend analysis may indicate that regulatory action to restrict certain activities is necessary… A groundwater quality certification program, similar to the existing water quality certification program for surface and coastal waters may be developed As groundwater contamination is more clearly understood, further controls to address emerging problems and issues will be developed and implemented" (DOH, 1990, pp. V-2, V-3).

While we are pleased by these indications that DOH recognizes the need to move toward preventive actions, we are disturbed by the lack in the DOH Protection Strategy of any kind of schedule for actual movement in this direction. Indeed, one of the statements quoted above suggests that no real effort will be made to establish preventing actions until trend analysis has taken place, and as we have seen above, trend analysis is not yet possible under the current monitoring strategy.

The DOH Protection Strategy does include a chapter describing potential types of preventive mechanisms, which we will list here because a number of worthwhile approaches have been suggested: establishment of narrative standards that would contain general prohibitions on discharge of designated contaminants; requiring the licensing or permitting of certain discharge sources; setting effluent limits for discharges; adopting performance standards establishing zones for discharge; establishing facility design requirements; developing best management practices for diffuse contaminant sources; controlling land use through zoning, siting and construction regulations or public acquisition; and establishment of cleanup regulations. Many of these mechanisms will undoubtedly be needed in Hawai'i, and the development of their application in ways suited to Hawai'i's needs will require considerable thought and public dialogue.

Unfortunately, however, the five-year workplan laid out in Chapter, XV of the Strategy does not provide a process or a schedule to move forward on the adoption of preventive measures. In contrast, the workplan does provide a good description of the process that will be followed to develop other elements of the program, such as a long-term monitoring strategy. The lack of a clear plan leading to the adoption of preventive measures makes us question how strongly DOH is committed to taking this difficult step.

Goal of the Protection Strategy

The stated goal of the DOH Protection Strategy is one, which NRDC strongly endorses: "The goal of the Groundwater Quality Protection Strategy is to protect human health and sensitive ecosystems through the protection and enhancement of the quality of groundwater throughout the State of Hawaii" (DOH, 1990, p. 111-1). NRDC similarly supports the companion statement that this goal "Will guide policy decisions with a determination that no avoidable pollution is 'acceptable'" (DOH, 1990, p. III1). Unfortunately, however, the strength of DOH's commitment to this goal must be questioned in light of the final caveat in the paragraph: “(However, considering our limited budget and staff resources we must prioritize efforts to protect groundwater based on existing and projected beneficial uses)” (DOH, 1990, p. 111-1). That the state of Hawai'i is not in fact committed to full protection of all groundwater resources becomes even more apparent in the DOH Protection Strategy's subsequent discussion of "anti-degradation policy" and "differential management strategy.”

The term "anti-degradation policy" typically implies a policy that will prevent all further degradation, or pollution, of water resources. In tile DOH Protection Strategy, the phrase takes on a slightly different meaning. Under the DOH policy, degradation of water quality is not to be allowed for those water resources with existing or future beneficial uses, *with highest priority being given to protection of the beneficial use of* drinking *water* (DOH, 1990, p. IV-1). Implicit in this approach is the decision not to attempt to protect those groundwater resources that are not currently being used beneficially or currently projected for future beneficial uses.

The basis for this policy is apparent in the candid statement of the conclusion that, “While non-degradation of [all] groundwater is an admirable goal, it is not a practical policy” (DOH, 1990, p. IV-1). This conclusion is in turn based on the assumption that, “Non-degradation cannot be accomplished unless all existing and future septic tanks, all land application systems for recycling wastewater, and landfills are prohibited” (DOH, 1990, p. IV-1). The argument against this view is expressed well in the groundwater protection strategy adopted by the state of Iowa, which adopted a resoundingly unambiguous goal of non-degradation for its program: “People have argued that all of man's activities affect water quality and society must instead accept degradation, define acceptable concentrations of contamination and control its location. While there is some truth to the arguments, these alternatives are undesirable. They presume that only certain aquifers are worth protecting, and that acceptable contamination can be defined for both existing and possible uses of the water” (Hoyer, et al., 1987, p. 43). NRDC strongly believes that it is possible to design many of these activities in a way that will prevent or at least minimize groundwater contamination, and that protection of all of Hawai'i's groundwater resources should not be regarded as an ephemeral or impractical goal. As it was put in Iowa's strategy, it is better to "attempt a worthy goal that is difficult to reach rather than to guarantee success with goals that provide little benefit" (Hoyer, et al., 1987, p. 44). Flowing from the anti-degradation policy discussed above is DOH's "differential management strategy' (DOH, 1990). The basic philosophy of the differential management strategy is to set and enforce different levels of protection for different aquifers or water sources, depending on their importance for beneficial uses (primarily drinking water) and on water sources, depending on their importance for beneficial uses (primarily drinking water) and on their vulnerability to contamination. It is essentially a triage management system that has a certain amount of intuitive appeal in this era of limited resources, and indeed the EPA has encouraged states to adopt differential management strategies in their groundwater programs. Environmentalists, however, have long been opposed to the differential protection approach for a set of equally practical reasons. While it may be too late to dissuade Hawai'i from taking a differential approach to groundwater protection management, it is still critical to ensure that these practical considerations are addressed.

The first problem with this approach is one inherent in the difficulties of groundwater classification, which the report correctly identifies as the "key element" of the differential management strategy: "Groundwater classification establishes the basis for a systematic approach to designating areas where aquifers need to be protected and restricting activities that constitute a probable threat of pollution to groundwater" (DOH, 1990, p. V-1). The Hawai'i program is to be based on a classification scheme developed by the EPA, which divides aquifers into the following three categories:

Class I-"Special Groundwaters": Waters that are "highly vulnerable to contamination because of the hydrological characteristics of the areas under which they occur" and are irreplaceable drinking water sources or ecologically vital (DOH, 1990, p. X'V4).

Class II-"Current and Potential Sources of Drinking Water and Waters Having Other Beneficial Uses": All other groundwater currently used or potentially available for drinking water or other beneficial uses (DOH, 1990, p. XV-5).

Class III-"Groundwater Not Reasonably Considered Potential Sources of Drinking Water and of Limited Beneficial Use': Heavily saline or contaminated groundwater (DOH, 19,90, p. XV-5).

The classification scheme thus represents a logical progression leading from the greatest level of protection for existing drinking water supplies to the lowest level of protection for waters that are unlikely ever to be viable drinking water sources. The problems arise, however, not from the theory but from its practice. First, the ability to provide adequate protection for key groundwater resources under this system depends heavily on the adequacy of groundwater mapping, and especially on the level of certainty about groundwater movement from one aquifer to another. If water classified as a Class 11 or III source is incorrectly assumed to be isolated from a Class I aquifer, insufficient protection may be provided to the Class I source. The prudent way to deal with this situation would be to provide *equal*, rather than *different*, levels of protection in cases of uncertainty. Indeed, EPA's intention is that the differential management strategy be used to prioritize management actions, but not to develop different levels of protection (pers. comm., Doris Betuel, EPA).

The other issue that often arises in efforts to develop differential management strategies is the question of what resources are likely to become future drinking water sources. The notion underlying Class III is that waters now considered unpotable will be equally worthless in the future, and thus there is little point in trying to prevent their further degradation. This assumption overlooks the strong likelihood that changing economics and technology may very well result in the development of water supplies in Hawai'i now considered to have no beneficial use. Desalinization, which has been discussed as an option to provide drinking water for new development on O'ahu, may well become economically viable - for example, a demonstration plant began operation this year. Thus, reconsideration of some of the waters designated Class III may be required. Indeed, it is EPA's intention that the vast majority of groundwater resources in Hawai'i
be included in Class I and II, rather than Class III (pers. comm., Doris Betuel, EPA).

In short, we are concerned that the emerging classification system may result in the failure to protect significant portions of Hawai'i's valuable groundwater resources. Given the limited extent of the resource and Hawai'i's very heavy dependence upon it, such a course does not seem prudent.

Public Participation Plan

One of the key elements of a strong groundwater protection program is meaningful public education and involvement. As was stated in Iowa's protection strategy: "Public confidence ... [is] crucial to the success of groundwater protection programs. There must be confidence that policymakers have the information needed and the ability to act in the [state's] interest. Policies must be understood and supported by the public. Thus, the public needs to learn what has been gained from research and water quality monitoring' (Hoyer, et al., 1987, p. 45).

While DOH did consult with a Groundwater Technical Advisory Committee, which included representatives of the public, in developing its Protection Strategy, the Strategy does not provide for ongoing public education and involvement as the tasks identified in the five-year workplan go forward. Without an active public participation program, it is unlikely that the public will understand the need for, and ultimately be willing to support, the level of resources and restrictions on activities needed to address the problem,

Recommendations

We recommend that DOH take the following actions in order to address the deficiencies in the adopted strategy described in the previous section. First, we recommend that DOH make every effort to use the new USGS water availability-monitoring program as the basis for an expanded quality-monitoring program. We urge DOH to continue pressing the U.S. EPA for funds and/or laboratory support to analyze the samples collected by USGS on O'ahu and the other islands. If the federal funds are not provided or are insufficient, we recommend that DOH convene a group of agency officials and interested members of the public to develop a proposal and support for an alternative funding mechanism.

Second, NRDC strongly urges DOH to develop immediately a workplan for the adoption of preventive measures. The workplan should be prioritized according to the perceived risk from various activities that may cause groundwater contamination in Hawai'i. For example, the development of preventive measures aimed at reducing agricultural pesticide migration into groundwater should receive relatively high priority in the workplan. The workplan should establish a process to evaluate the effectiveness of an array of strategies for preventing groundwater contamination from each different potential source or set of sources. The workplan should provide for evaluation of the preventive mechanisms discussed in Chapter XI of the Strategy at a minimum. DOH should also request input from the public on additional preventive measures that should be included in the workplan for consideration.

Third, we urge DOH to adopt an unambiguous goal of non-degradation for all groundwater resources in Hawai'i. Similarly, we recommend that DOH employ a differential strategy only as a means of prioritizing management efforts, and that it reject a strategy of differential protection.

Last, we recommend that DOH develop a broad-based, ongoing public education and participation program. The program should be designed to provide a continuing flow of information to the public at large and interested groups about the results of monitoring efforts as they are reported. Monitoring results should be reported completely in quantitative terms, and should also be accompanied with policy analysis regarding their significance. The public participation program should also be designed to elicit recommendations from the public about DOH's efforts to protect Hawai'i's groundwater, ranging from design of the monitoring program to imposition of use restrictions. It is only through public awareness and involvement that DOH will win the support it needs to ensure that Hawai'i's groundwater remains safe.

Appendix: Chemicals Found in Hawai'i's Groundwater

CHEMICAL	COMMON USE	POSSIBLE HEALTH EFFECTS	APPLICABLE STANDARDS (PARTS PER BILLION)
2,4-D	Herbicide	Weakness; stupor, hyporeflexia; muscle twitching,, convulsions; dermatitis	EPA MCL: 70
1,2-DCP	Nematocide	Gastrointestinal irritation; liver and kidney damage,- probable carcinogen	EPA MCL: 5
Aldrin	Insecticide	Possible carcinogen	
Ametryn	Herbicide	Liver damage	EPA LHA.- 60
Atrazine	Herbicide	Heart and liver damage; Fetal/child development effects; possible carcinogen	EPA MCL: 3
Benzene	Fumigant product	Reproductive system effects; probable carcinogen	EPA MCL 5
Bromacil	Herbicide	Moderate toxicity	EPA LHA.- 90
Bromodichlomethane	Organic synthesis	Possible carcinogen	EPA MCL: 100
Bromoform	Pharmaceutical manufacturing; solvent; ingredient in fire-resistant chemicals and gauge fluid	Possible carcinogen	EPA MCL: 100
Carbon tetrachloride	Soil fumigant	Liver, kidney and lung damage; probable carcinogen	EPA MCL- 5
Chlordane	Insecticide	Liver, kidney and central nervous system damage; possible carcinogen	EPA MCL: 2
Chloroform	Fumigant; insecticide	Central nervous system depressant; possible carcinogen	EPA MCL- 100
DBCP	Soil fumigant	Male reproductive system, liver, and kidney damage; probable carcinogen	EPA MCL: 0.2 DOH MCL: 0.04

Appendix: Chemicals Found in Hawai'i's Groundwater (cont'd)

CHEMICAL	COMMON USE	POSSIBLE HEALTH EFFECTS	APPLICABLE STANDARDS (PARTS PER BILLION)
DCE	Solvent; refrigerant, pharmaceutical manufacturing	Nervous system depressant	EPA MCL: 5
DDT	Pesticide	Liver, kidney and central nervous system damage; possible carcinogen	
Dibromochloromethane	Manufacture of fire extinguishing agents, aerosol propellants, refrigerants, and pesticides; can form as a result of water chlorination	Possible mutagen	EPA MCL: 100
Dichlorobenzene	Process solvent; synthesis intermediate	Hemolytic anemia; liver necrosis	EPA MCL: 75-600*
Dichloropropane	Solvent; trace contaminant in pesticides	Decreased red blood cells; liver and kidney damage	EPA MCL: 5
Dichloropropenes	Soil fumigant; nematocide	Mutagen	
Dieldrin	Insecticide	Liver, central nervous system, kidney, and adrenal gland damage; probable carcinogen	
Diethylphthalate	Insecticide		
EDB	Soil fumigant	Male reproductive system, liver, gastro-intestinal, and adrenal gland damage; probable carcinogen	EPA MCL: 0.05
Ethylbenzene	Manufacture of styrene synthetic rubber and cellulose acetate; solvent; gasoline component; insecticide component		EPA MCL: 700
Freon	Refrigerant; propellant gas	Asphyxia; cardiac arrhythmia; cardiac arrest	
Freon 11	Aerosol propellant; refrigerant; foaming agent	Dizziness; tremiors; unconsciousness; cardiac arrhythmia; cardiac arrest	
Hexazinone	Herbicide		EPA LHA: 200

***MCL for para-Dichlorobenzene is 75 ppb; MCL for o-Dichlorobenzene is 600 ppb.**

CHEMICAL	COMMON USE	POSSIBLE HEALTH EFFECTS	APPLICABLE STANDARDS (PARTS PER BILLION)
Lindane	Pesticide	Nerve damage and central nervous system seizures; liver and kidney damage; immune system suppression; possible carcinogen	EPA MCL: 0.2
Methyl chloride	Methylating and Chlorinating agent; extractant, solvent; refrigerant; propellant; drug manufacture intermediate	central nervous system depressant; Possible carcinogen;	
Methylene chloride	Solvent; paint remover, degreaser	Possible carcinogen; mild narcotic	
PCE	Solvent; fumigant; chemical intermediate	Central nervous system depressant; liver and kidney damage; probable carcinogen	EPA MCL: 5
PhenolT	Various manufacturing	Various systemic effects	
Simazine	Herbicide	Liver, kidney and brain damage; possible carcinogen	EPA MCL: 4
TCE	Solvent; dry cleaning agent; intermediate in pesticide production	Central nervous system depressant; heart effects; liver and kidney damage; probable carcinogen	EPA MCL- 5
TCP	Trace contaminant in pesticides	Decreased red blood cells,- liver and kidney damage	HDOH MCL: 0.8
Toluene	Manufacture of benzene; chemical feedstock; solvent; fuel component	irritation of eyes, respiratory tract, and skin	EPA MCL 1,000
Xylene	Solvent; paint constituent; chemical feedstock; various manufacturing	Central nervous system depressant	EPA MCL: 10,000

Sources:
-40 C.F.R. § 141 (1992).
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MCL = Maximum contaminant level   LHA = Lifetime health advisory

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