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MAPPING PESTICIDE/WATER SUPPLY RELATIONSHIPS
IN MASSACHUSETTS

by

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ABSTRACT

During 1984 and early 1985, the Massachusetts Department of Environmental Quality Engineering, Division of Water Supply, became aware that fairly widespread contamination of ground water existed, involving several commonly used pesticides: Aldicarb (Temik), Ethylene Dibromide (EDB), 1,2-dichloropropane, and Dinoseb. Because of the widespread contamination and the presence of public water supplies in the same aquifers, the Division of Water Supply elected to study the problem to determine relationships between pesticides and water supplies.

The Connecticut River Valley, intensively cultivated with crops on which the chemicals in question were used, and where much of the known problem was located, was selected as the test locality. The area delineated includes all of some 20 towns (6 percent of the Commonwealth). Stone & Webster Engineering Corporation was selected as the consultant for the work.

For each of the towns, a series of maps and reports were prepared as overlays to the standard 1:25,000 USGS 7.5' topographic map: (1) Pesticide use maps for 1972 information and 1984/85 information; (2) public water supply sources and system piping; (3) known pesticide contamination of water supplies, public and private. For each community, a report was prepared to go with the map. This included (1) statistical information and specific location of acreages where pesticides were expected to have been applied, together with known information; (2) historical information on the use of pesticides in each community; (3) a review of applicable literature; (4) an evaluation of the mapped

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information; and (5) recommendations. A Valley-wide report was prepared as well. The Department is using this information to help each of the subject towns to prepare appropriate protection measures, as well as to guide the Division of Water Supply's prevention and remediation programs.

Sample product and case information are presented here, together with some of the recommendations and the Division's observations on the methods of study and further work on the topic. Related database development and public/private responses to the specific contamination incidents are presented in other papers in this symposium.

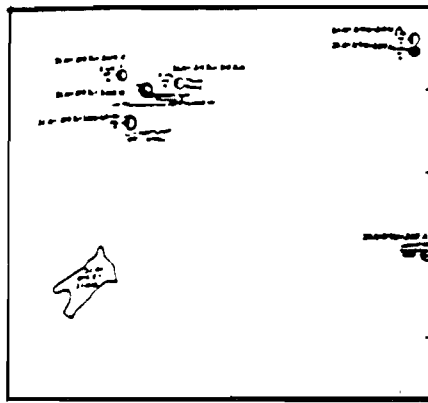
BACKGROUND

In protection and management of natural resources such as water supplies, mapping of land uses in an area is of demonstrated value. Several years ago, one of the authors and a colleague (Bowley and Roy, 1981) presented a paper at the Atlanta National Water Well Meeting, detailing such a mapping effort in developing a Water Supply Protection Atlas. Briefly, that atlas involved preparing and manually drafting four 1:25,000 scale transparent overlay sheets for each of the approximately 200 USGS 7.5' quadrangle topographic maps covering Massachusetts. The first overlay described public water sources; the second, waste sources; the third, groundwater availability; and the last, watersheds for each named stream basin in Massachusetts. (A sketch example is shown in Figure 1.) It was stated at the time of release that these maps represented "best available information" and that a future update was intended. A complete set was distributed among our four regional offices, and copies of the sheets for each of the 351 cities and towns were distributed to local officials at regional public meetings, for use as a tool in water supply protection. The maps have proved to be very useful, and seven years later are in constant use. Revisions have been made on the office original copy, with an eye toward general re-issue.

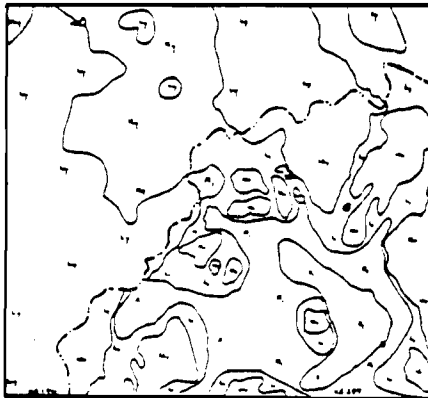
Therefore, when (as a result of state testing and current literature) it became clear in 1985 that agricultural chemicals presented a potential threat to water supplies, the Massachusetts Department of Environmental Quality Engineering's Division of Water Supply decided to develop a more detailed set of overlays for specific qualifications for assessing the effects of agricultural chemicals. The Connecticut River Valley was selected as the target area of the study on the basis of the intensity of agricultural activity there and the results of water quality testing conducted on public and private water supplies through the cooperation of this Department with the Department of Food and Agriculture (MA-Interagency Pesticides Task Force 1985, 1986).

The study area was narrowed down to 22 USGS 7.5' quadrangles encompassing 20 subject towns. Four additional atlas sheets were proposed for each of these quads, showing:

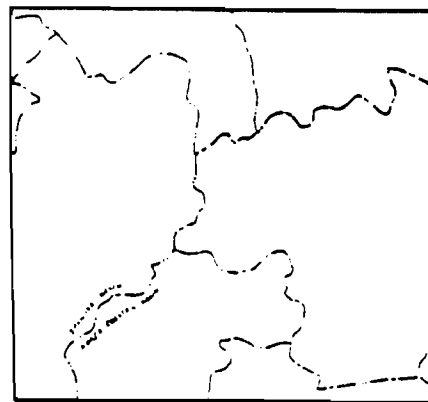
- Map of tested water supplies showing contamination at testing;
- Updated maps of public water sources, adding distribution mains; and



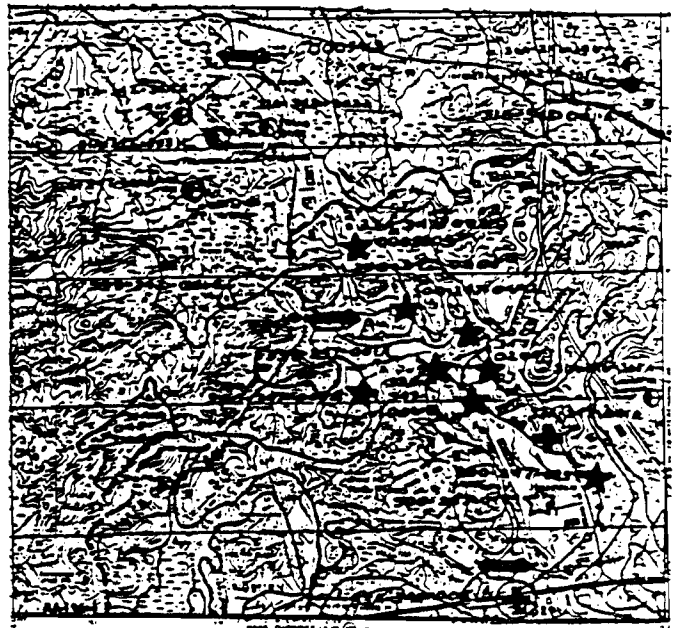
WATER SOURCES OVERLAY
(ORANGE)



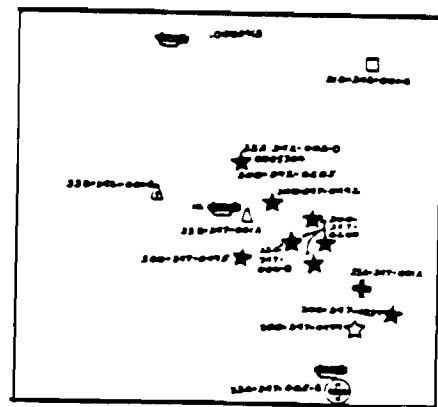
AQUIFER INFORMATION OVERLAY
(BLUE)



RIVER BASINS OVERLAY
(BLACK)



COMPOSITE OF ALL OVERLAYS
(Monochromatic Representation)



WASTE SOURCES OVERLAY
(RED)

Figure 1
Reduced Portion of a Representative Quadrangle Groundwater Protection Atlas

- Two agricultural land use maps, comparing crop changes over a 13-year period and detailing (insofar as possible) individual crop types, in order to obtain an estimate of agricultural chemical application and the relationship to water supplies - contaminated, uncontaminated, and not yet tested.

Information sheets on characteristics of each of the seven agricultural chemicals selected for detailed testing in the subject area were planned, and tables indexing recommended crop applications of agricultural chemicals approved for use in Massachusetts were outlined. The seven chemicals Alachlor, Aldicarb, Carbofuran, Dinoseb, 1,2-Dichloropropane, Ethylene Dibromide, and Oxamyl, were chosen because they represent the principal chemicals applied in the area.

It was decided to develop a statewide report for the use of the Department and to provide each city and town involved with a set of overlays specific to that locality which included a 1000 ft border of information from the surrounding towns. This was done to ensure that areas of possible concern in other jurisdictions could be observed and taken into account in planning protective measures or testing.

METHOD

Consultant responses were reviewed through the RFP process. To the pleasure of project staff; some of the respondents proposed the use of computer-based mapping and data storage techniques to save on time and production costs. This would afford the Department the opportunity to examine Geographic Information Systems (GIS) as a possible tool for atlas revision without a major commitment for equipment and programming up front, and would also provide a dynamic means of handling changing information.

The successful responder (Stone & Webster Engineering Corporation) proposed INTERGRAPH as their GIS, and agreed to provide the Department with maps, reports, and the tapes necessary to continue the program. It was determined that this system could be translated into ARC-INFO, a system used by the US Geological Survey and others, and one being considered for use by the Department. The mapping portion of the project is discussed below; database management, elsewhere.

Two complete sets of maps and a Valley-wide master map and 50 copies of the report including detailed town recommendations and reduced copies of the maps and overlays were provided to the Department for its own use, and reports with full-sized town maps were prepared for each town. These were distributed at regional informational sessions for groups of towns. The sessions included discussion of the uses of the materials, demonstration of the GIS system, and arrangements for individual technical assistance. Maps and reports were given to representatives of local Boards of Health, who signed for them to provide a list of local contacts for use in answering anticipated inquiries.

THE MAPS - Water Supply Overlay

In the course of developing and subsequently working with the much-used atlas, it had become apparent that "best available information" was not necessarily the most accurate information. Because water supply locations were the foundation of this effort, the first priority was to verify and expand this information. The overlay sheet developed (Figure 2) incorporates this work. Information was supplied to the contractors by the Department, town engineers, and water Superintendents and Commissioners, and refined in field visits. In addition to source location, the distribution systems within each town were mapped (if such existed) to provide an indication of the areas served by public and by private supplies. This would allow for a determination of possible affected areas, as well as potential sources of remedy when a public system might be extended to an affected area of private supply, or to interconnect with another public system to assist in alleviating contamination problems on a temporary or permanent basis. To facilitate this analysis, pipe sizes were indicated by line quality on the overlay. This information presents, in quickly reviewable graphic form, information contained in many files and reports, assisting in a quick focus on the issue at hand. The more detailed technical data can then be accessed as necessary.

Agricultural Chemical Contamination Overlay

Water supplies contaminated by at least one of the seven agricultural chemicals previously cited were mapped based on data provided by the department. The samples and analysis behind the data were conducted in 1983-1986. Of the 358 ground and surface water samples analyzed, a total of 146 sites showed positive results for at least one of the seven chemicals. (As a cautionary note, it should be observed that the mapping presents only positive results: it does not show the total array of locations sampled; and not all sites were reviewed for the presence of all seven of the chemicals).

These results are presented as dark symbols for the locations having positive results over the Massachusetts Interim Drinking Water Guidelines (IDWG; Table 1); light symbols represent the locations either under the IDWG, or where resampling showed a concentration previously over the IDWG to be below them or not detected. Locations with positive results are accompanied by a map reference number, and the well depth if applicable or available, as may be seen in Figure 3.

Pesticide-Related Land Use Overlays

The pesticide-related land use portion of the study provided the identification of past and current agricultural activities, golf courses, and railroad and transmission corridors within the 20 town study area. These overlays were generated from aerial photography interpreted and mapped by Stone & Webster. The original intent was to use 1984 photographs which would be supplemented by 1984 mapped data supplied by the University of Massachusetts for use in ground-truthing. Due to the

(Note: This figure is a reduction of an overlay to a USGS composite map originally produced at a scale of 1:25,000)

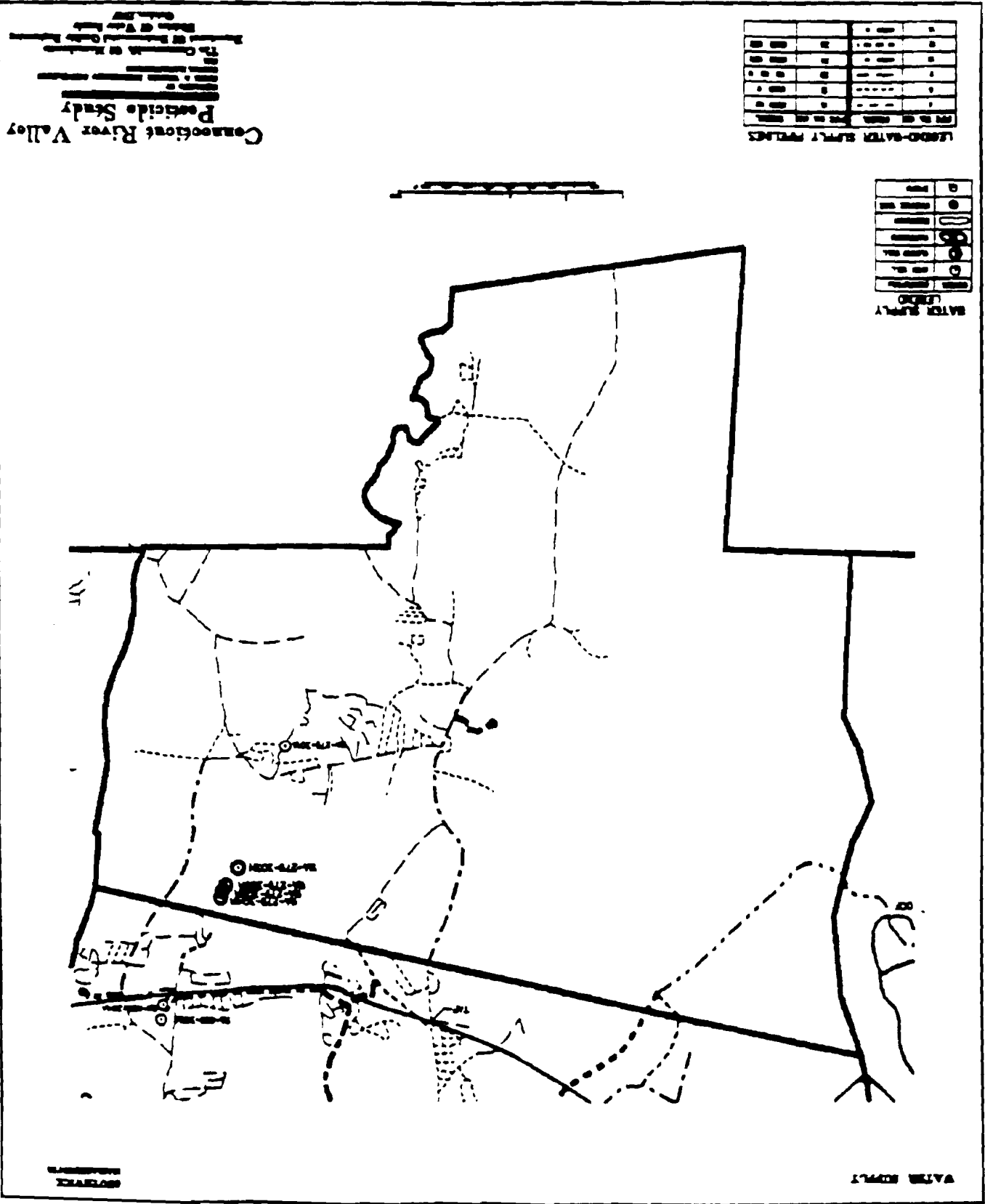
Figure 2

LEGEND-WATER SUPPLY POINTS

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WATER SUPPLY LEGEND

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Connecticut River Valley
Pesticide Study

State of Connecticut
Department of Environmental Protection

1978

UNIVERSITY OF CONNECTICUT
SCHOOL OF FORESTRY

STATE OF CONNECTICUT
DEPARTMENT OF ENVIRONMENTAL PROTECTION

TABLE 1

COMMONWEALTH OF MASSACHUSETTS
INTERIM DRINKING WATER GUIDELINES

Alachlor	2.0 ppb
Ethylene Dibromide	0.04 to 0.10 ppb (supply monitored for up to two years)
	0.10 ppb (supply closed)
1,2-Dichloropropane	1.0 ppb
Dinoseb	5.0 ppb
Carbofuran	10.0 ppb
Aldicarb	10.0 ppb
Oxamyl	50.0 ppb

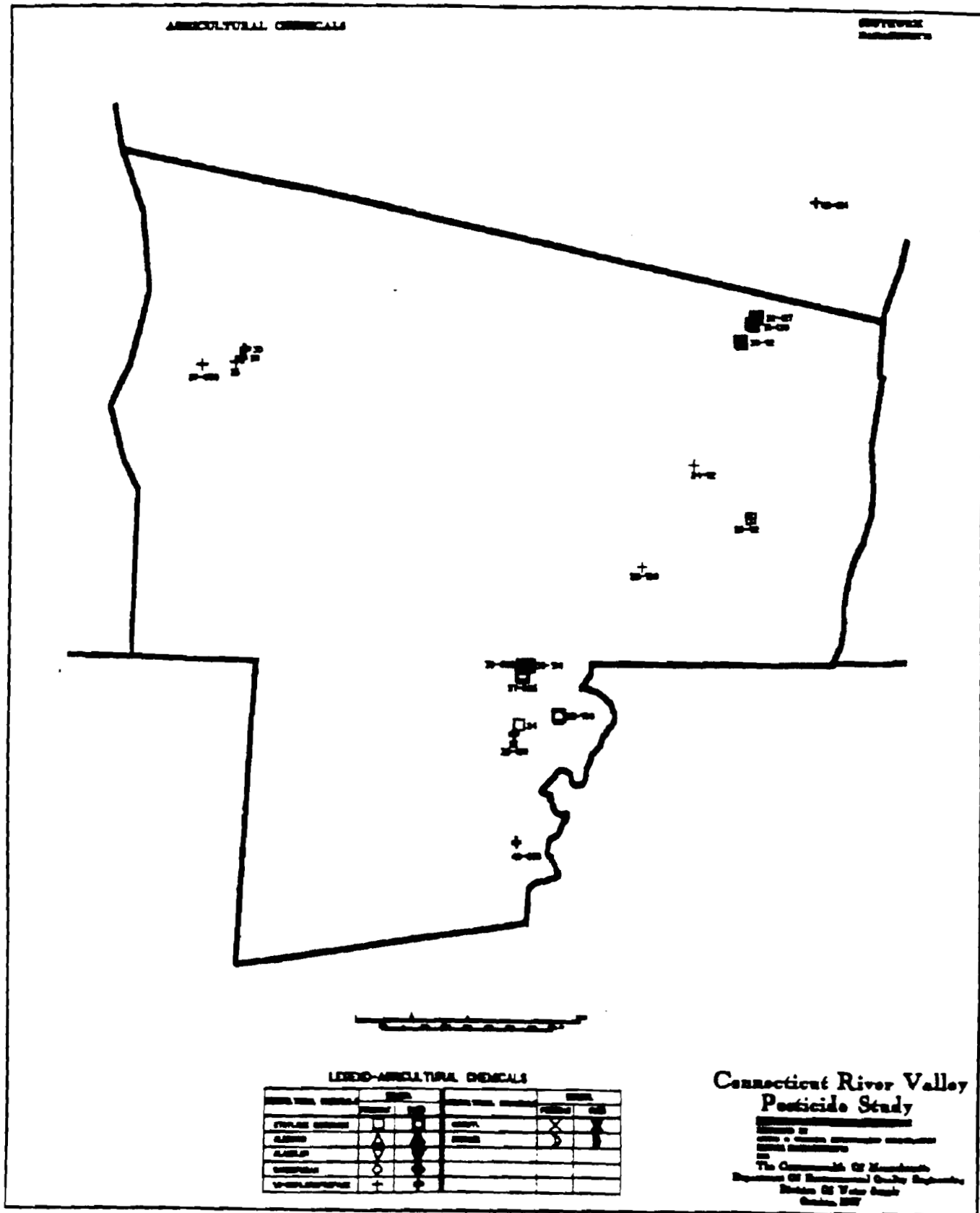


Figure 3
 (Note: This figure is a reduction of an overly to a USGS composite map originally produced at a scale of 1:25,000)

lack of a complete set of photographs from 1984 flights for the entire study area, 1985 photographs provided by the Department of Forestry were used instead. Both the 1985 and the 1972 photographs available for use presented certain problems in interpretation related to the season of photography and related seasonal differences and/or similarities in crop "signatures." This resulted in the use, for example, of a "Tilled Land" designation among the crop signatures. The 1972 photos also presented problems in clarity which possibly affected assignment of land use signatures. Both sets of photography presented problems in ground truthing. (For example, Agricultural Soil Conservation and Stabilization Service (ASCS) data for one of the three countries showed "Mixed Vegetables"; the other two did not.

After consultation with the department, the consultant developed categories which could include the basic level of useful information available, as well as provide a reasonable accuracy in delineation. Crop information in this presentation must therefore be regarded as "best available information," subject to verification at the local level but providing a reasonably accurate guide to use of the land in agriculture.

This database can be periodically reviewed and compared to future land use information, for the purpose of tracking changes and monitoring potentially sensitive areas. By comparison of the Agricultural Land Use overlays with each of the others, insight may be gained regarding potential contamination sources and chemical migration.

The most apparent trend to be noted from this 13-year comparison mapping effort is the overall reduction in the area of land devoted to agriculture (Table 2). For the whole study area, this represented a loss of some 34,000 acres from agricultural production to development and other uses. However, the proportions among the various crop designations remained statistically constant over this time, with one exception: areas dedicated to growing shade leaf tobacco decreased from 3,234 acres in 1972 to 794 acres in 1985. This activity is concentrated at present in the towns of Southwick and Westfield, which contain together some 522 of these 794 acres. A sample representing the agricultural land use overlays may be seen in Figure 4.

RESULTS

About half of the sites sampled for water quality were in the Town of Whately, where extensive contamination to private groundwater resulted in a special appropriation in the Department's budget to underwrite development of a town water supply where none had previously existed. The remaining water samples were collected from the other towns in the study, except for Northfield and Gill, where none were taken. The distribution of samples was skewed because the original impetus was to sample for pesticide contamination in and around tobacco and potato fields (1985 Summary Report: Interagency Pesticide Monitoring Program). Among the other public and private supplies tested, one auxiliary well of the South Deerfield Water District and four wells in Southwick belonging to the town of West Springfield have been closed. A total of eight of the 15 towns

TABLE 2
TOTAL AGRICULTURAL ACREAGES
1972 AND 1985

TOWN	TOTAL ACRES	1972		1985		DIFFERENCE ¹ (1985-1972)	% CHANGE
		AGRICUL- TURAL ACRES	% OF TOWN	AGRICUL- TURAL ACRES	% OF TOWN		
Agawam	15,168	4,665	31	2,373	16	-2,292	-49.1
Amherst	17,600	6,748	38	3,062	17	-3,686	-54.6
Belchertown	33,728	4,721	14	2,825	8	-1,896	-40.2
Bernardston	14,976	2,419	16	1,732	12	-687	-28.4
Deerfield	20,416	6,261	31	5,286	26	-975	-15.6
Easthampton	8,576	2,463	29	1,553	18	-910	-36.9
Gill	9,536	2,830	30	1,577	17	-1,253	-44.3
Granby	17,792	2,622	15	2,469	14	-153	-5.8
Greenfield	14,528	3,144	22	1,774	12	-1,370	-43.6
Hadley	15,744	9,243	59	6,128	39	-3,115	-33.7
Hatfield	10,112	4,741	47	1,838	18	-2,903	-61.2
Montague	18,880	2,448	13	1,807	10	-641	-26.2
Northampton	22,144	4,810	22	2,380	11	-2,430	-50.5
Northfield	22,656	4,190	18	2,776	12	-1,414	-33.7
South Hadley	11,328	2,191	19	1,179	10	-1,012	-46.2
Southampton	18,496	3,329	18	2,403	13	-926	-27.8
Southwick	19,584	5,089	26	3,672	19	-1,417	-27.8
Sunderland	9,088	3,618	40	2,149	24	-1,469	-40.6
Westfield	29,952	5,405	18	1,246	4	-4,159	-76.9
Whatley	13,184	4,027	31	2,506	19	-1,521	-37.8
TOTAL	343,488	84,964	25	50,735	15	-34,229	-40.3

¹Difference equals loss of agriculture land between 1972 and 1985

where public water supplies were tested showed some contamination of the supplies.

Contamination was generally found in shallow wells adjacent to fields where active farming occurs. There was a general correlation between the chemicals found in the wells and the chemicals recommended for the crop type grown near the contaminated wells. There were also some deep large capacity wells that were contaminated. This may have arisen through either movement of contaminants along the well bore, or as was discovered in South Deerfield and Southwick, migration of pesticides from more distant forces.

Contaminated supplies were listed and characterized in tabular form for use with the maps, and a set of tables listing chemicals recommended for use in Massachusetts and the crop types for which they were recommended were presented in appendices to the report.

Recommendations were provided for further areas of investigation and action, town-by-town and overall. These generally included: (1) conducting aerial surveys to map present agricultural uses; (2) mapping changes on the distribution systems of public water supply changes; (3) mapping of all private groundwater supplies and including depths of well screens; (4) establishing better correlations between water quality and agricultural activity; (5) systematically surveying areas of potential problems to determine chemical usage; and (6) systematically testing of water supplies for specific chemicals of concern based upon crop type in the vicinity of the supplies and the chemicals which were used on those crops. In addition, the Department suggests careful attention to agricultural activities conducted within the "zone of contribution" to public water supplies. As these water supplies are tested more frequently due to their potential vulnerability, some control or restriction on use of certain chemicals within these areas may be in order. The Department is exploring such activity in terms of these critical areas in cooperation with the Massachusetts Pesticide Board. The regulations adopted for maintenance of rights-of-way already embody such restrictions. The Department has also continued to supply local boards of health with information related to pesticides and water supplies, including a compilation of local controls (Saia, 1988).

In conclusion, a new water supply protection tool has been developed, and a new system for atlas revision has been modeled. Time will gauge the success of the effort. The Department of Environmental Quality Engineering, Division of Water Supply and its contractor, Stone & Webster Engineering, hope that presentation of the work here will be of use to other states in their continuing effort to safeguard sources of drinking water.

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