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Water Science and Technology:
Some Lessons from the 20th Century
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Outline

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The date of this lecture and the name of the man it honors call up two related chains of recollection. We are approaching the end of the 20th century, and the 108th year after the birth of Abel Wolman (1892-1989) who contributed in a notable degree to the unfolding of water science, technology, and policy during much of that century. This leads to a few reflections upon Abel, and to suggestion of several lessons learned during the 1900’s that may be relevant to achieving wise management of our water resource in the century ahead. The lessons relate to the intertwining themes of water and environmental policy. The nation still has not fashioned policy aims, operating criteria, and organization that fully recognize the interdependence of the health of ecosystems and of social systems in efforts to achieve a sustainable quality of life through water management. It can do so by applying lessons from the evolving water science and technology of the past century.

Abel Wolman - His Contributions

Abel first worked professionally on a water problem (for the U.S. Public Health Service) in 1913. I did not encounter him personally until 1935 when I served on the staff of the Water Committee of the National Resources Board, which he chaired for the next six years. He published his first scientific article in 1916 and his last in the mid 1980s, and I had the pleasure of studying many of them and of editing a volume of his selected publications in 1969. There was no question but that his contributions were original and often highly influential, beginning with such problems as bacterial removal in water filtration plants and the pioneering of chlorination for domestic water supply. Perhaps his most comprehensive analysis of
water problems was the report in 1962 on "Water Resources" that he wrote for the Committee on Natural Resources of the National Academy of Sciences, without benefit of staff or committee members. In it he identified what he considered the more significant problems in the water resources field, and the areas in need of research. Examples of needy fields were: interdisciplinary training; ground-water processes; techniques for evaluating systems of water management; evaporation suppression and transpiration control; and improved water-purification methods and techniques for forecasting pollution damage.

To be in the Wolman tradition, this talk should be extemporaneous, comprehensive, felicitous in expression, punctuated with gentle wit and soft-spoken sarcasm, and end with a lucid summation that sends hearers away smiling, but a bit puzzled by some of the generalizations. I fear that I can only satisfy the last of those prescriptions.

In focusing concern upon a few lessons from experience with past water management the intent is not to enumerate all of those aspects of water science and technology that seem to call for intensified attention in the beginning of the next century. Rather, the object is to suggest a few criteria, which, if applied more thoroughly, would lead to selection of high priority goals. The argument is that insufficient emphasis upon them has resulted in ineffective and sometimes counter-productive measures in a number of sectors of resource management.

Nor is the intent to offer a comprehensive assessment of all the prevailing policies with respect to water and environment in the United States. We now have a number of such appraisals, and their quality and coverage will be enhanced by the several visions that will be widely discussed--both in the United States and for the world--in the year ahead. A major challenge is to assure that proposals for further research action are thoughtfully appraised.

The experience of the 1900s in the United States suggest that in the development of water and related environmental management there are a few considerations that have been neglected and now need explicit attention.

**Principal Changes in U.S. Water Management and Environmental Policy during the 1900s**

As background for a look ahead, let us consider some examples of the principal changes in water management and environmental policy during the past century in the United States. They have much in common with changes in other parts of the world where international collaboration in water management took formal shape in mid-Century. A comprehensive account of Wolman's life and major contributions in the water field is to be found in the fascinating two-volume, 1,200 typewritten page, Abel Wolman: His Life and Philosophy: An Oral History by Walter Hollander, Jr, 1981, privately typed, Chapel Hill, NC. Most can be described in terms of: defining tasks for specific agencies, approval of evaluation criteria by the body politic;
outlining methods to be pursued by the responsible agency or agencies; and defining the stakeholders to be involved in decisions. Beginning with principal interest in single-purpose programs to deal with navigation, power, domestic and industrial water supply, irrigation, floods, management of forests, and wildlife conservation, by the third decade of the 1900’s and with the establishment of the Tennessee Valley Authority, attention shifted to multiple purpose development. The development of Federal water management activities up to 1960 is concisely documented by Beatrice Hart Holmes in A History of Federal Water Resources Programs, 1800-1960, (Washington, U.S. Department of Agriculture, Economic Research Service, 1972). By the sixth decade, public concern began to consider in more detail the environmental aspects of water development in a small but growing number of directions.

A large proportion of the activity after the 1920’s was carried out by agencies focusing on one or two purposes, and concerned with a few related aims, such as the Corps of Engineers for navigation and flood control, the Bureau of Reclamation for irrigation and power, the Federal Power Commission for power, the Forest Service for forest management, the Soil Conservation Service for soil conservation, and the Bureau of Biological Survey for wildlife. By the 1970’s, as had been predicted by the President’s Water Resources Policy Commission in 1950, most of the very promising sites for large dams and river improvements had been developed, and there was slowly increasing attention to environmental aspects of water management.

From the mid-1930’s there was a progression of national efforts to consider the implications of multiple-purpose efforts, and to unify all relevant public and private activities in a designated area. Beginning with the Mississippi Valley Committee (1934) and the NRB Water Resources committee (1937-43), there were the efforts of the President’s National Water Resources Policy Commission (1950), the Senate Select Committee on Water Resources, (1961), the Water Resources Planning Act of 1965, and the National Water Commission (1971). From some of those reviews, the Water Resources Council emerged, and carried out its coordinating activities, including basin committees or commissions, and State Water Resources research programs until abolished in 1982. An invaluable account of various Federal efforts to promote integrated planning starting with the Senate Select Committee on Water Resources is to be found in the oral history recorded by Martin Reuss, Water Resources People and Issues: Interview with Theodore M. Schad, (Alexandria: Office of History and Institute for Water Resources, U.S. Army Corps of Engineers, n.d., circa 1998). A second "valley authority" was never created. No national program yet seeks representative "watershed planning" for the entire country.

A series of strenuous efforts were made to establish criteria for evaluation of Federal water projects, beginning in 1965, and continuing in 1980 and 1983. A long series of efforts centering on the Corps of Engineers and studies generated at the Harvard Water Program and Resources for the Future examined the principles and guidelines employed in evaluating water projects. These took into account the provisions of the National Environmental Policy Act of 1969 (NEPA) which sought

Recent reviews such as the report of the Western Water Policy Review Commission and the discussions leading up to the Federal legislation have not yet had major impacts upon the organization, aims, and methods of Federal, State, local and citizen organizations concerned with water and associated environmental management. Western Water Policy Review Commission, Water in the West: Challenge for the Next Century, n.p. 1998.

Against this very brief review of selected changes in policy with respect to water and environment during the past hundred years, it may be helpful, using the same framework, to consider problems that appear to call for creative innovation in the years ahead. To suggest the types of factors that are candidates for change, two quite different combinations of water problems are examined. Those are related to the management of floodplains and the provision of, and disposal of domestic water supply. Other problems, such as management of wetlands and electric power generation, might be mentioned but the general lessons are, I believe, similar.

**Floodplains**

Federal organized concerns for the use of floodplains in the United States began after the great flood of 1927 on the lower Mississippi River, and slowly evolved, chiefly in response to major inundations. J.W. Moore and D.P. Moore, The Army Corps of Engineers and the Evolution of Federal Flood Plain Management Policy, (Boulder, CO: Institute of Behavioral Science, 1989). James Wright currently is completing for the Association of State Flood Plain Managers a history of national efforts in this field. Initially, the Federal role was to plan and build authorized channel, levee, and reservoir projects to control floods with various degrees of local participation, depending upon the type of project. That policy was modified in several ways in subsequent legislation. Flood control was incorporated where appropriate in integrated projects for navigation, power generation, and water supply. Some agriculture losses were the responsibility of the Soil Conservation Service, which dealt with them in watershed planning projects in which farmers carried a portion of the costs. The U.S. Forest Service maintained an interest in the relation of forest cover to floods. There never was a joint program for upstream and downstream activities in combination, although that was envisaged at an early date. L. Leopold and T. Maddock, Big Dams, Little Dams, and Land Management, (New York: Ronald Press, 1954).

Criteria for estimating the justification for building the designed works were the prospective net changes in national income, and expressed in benefit-cost ratios with the benefits taken as the prevention of losses that otherwise might occur. No
estimates were made of the benefits of floods to the maintenance of ecosystems or agricultural production. After the passage of the National Environmental Policy Act in 1969, all recommendations for any construction were required to carry a statement as to possible effects on biological systems. The Endangered Species Act of 1973 carried similar requirements, and specific provisions were made to protect wetlands in the Clean Water Acts of 1972 and 1977. The Environmental Protection Act of 1969 grew out of accumulating evidence of the effects of development projects on vulnerable ecosystems. A sample of the kinds of water activities contributing to that response is found in M.T. Farvar and J. P. Milton, Eds. The Careless Technology, Ecology and International Development (Garden City, NY: Natural History Press, 1972).

After the Federal Emergency Management Agency was established, it became interested in programs to mitigate the continuing burden of disaster losses. It now does this through support of activities in sample, "Impact," communities, but no mention is made of accounting for possible beneficial uses of floodplains. Nevertheless, FEMA currently is pursuing a Congressional directive to investigate the natural and beneficial uses of floodplains and has not yet submitted a report. A draft report is in preparation, but no policy recommendations yet have been issued.

As a small example of possible beneficial use, the opportunities to use unprotected floodplains for the cultivation of switchgrass leading to the manufacture of ethanol and generation of electric power with a minimum of air pollution have been ignored, and research on improvement of agricultural and refinery practices contributing to that end has been neglected. R. A. Sampson and J.A. Omieian. "Switchgrass: A Potential Biomass Energy Crop for Ethanol Production," Thirteenth North American Prairie Conference, 1995, 253-58, and W.L. Stout, G.A. Jung and J.A. Shaffer, "Effects of Soil and Nitrogen on Water Use Efficiency of Tall Fescue and Switchgrass under Humid Conditions," Soil Science Society American Journal, 1988, 52: 429-34. The exploration of such opportunities could proceed along with exploration of ways of reducing disaster losses through methods of prediction, disaster management, flood control and flood proofing.

A geographic study of land use in sample floodplains of the nation during the 20 years following enactment of the Flood Control Act of 1936 had showed that while protection had been provided against extreme flows in many areas, development occurred in other areas so that the toll of average annual flood losses continued to rise. G.F. White, et al., Changes in Urban Occupance of Flood Plains in the United States, Chicago: University of Chicago Geography Research Papers, No. 57, 1958. The Corps of Engineers thereupon established a special office to assist in floodplain management, and an Association of State Floodplain Managers was organized for assistance to local and state officials. The same trend in flood losses continued in subsequent years, and in the mid-1960’s two task force reports recommended that one possible measure to reverse the continuing growth might be a program of Federally-supported flood insurance linked with requirements of local land-use management. One of the task forces emphasized that the primary aim should be to
promote socially wise use of the floodplains rather than solely reduction of losses. That recommendation was never followed, and, likewise, its suggestion that the new program be tested to observe its effects before long-term policies were adopted was ignored. 89th Congress, 2d Session, A United National Program for Managing Flood Losses, House Doc. 465, 1966. Only during the past six months has the Federal Insurance Administration initiated a comprehensive assessment of the full effects of its 30-year program. There still is no definitive analysis of the extent, if any, that Federal flood insurance has encouraged increased vulnerability to floods or increased losses to natural systems or improved the social use of floodplains. Some of the reasons probably are the same as those explaining why other Federal water programs have not been evaluated: the reluctance of agencies to assess the full consequences of their authorized programs.

In 1998 the Office of Management and Budget issued a summary of a variety of 28 Federal Agency programs touching use of on floodplains, but those did not form a unified effort. U.S. Bureau of Management and Budget, (Compilation of Federal programs relating to Floods), 1998. In 1999 a joint group of urban planners writing on the subject of rising national losses from natural disasters, of which floods are a major contributor, argued that: "Federal programs make planning more difficult because they encourage the use of hazardous land and shield local governments and decision makers from financial losses in the disasters that inevitably follow." R. Burby, et al., "Unleashing the Power of Planning to Create Disaster-Resistant Communities," Journal of the American Planning Association, Vol. 65, in press.

Following the great Upper Mississippi Basin floods of 1993 comprehensive reports by Galloway and others were issued on the status and possible ways of improving national flood programs, but only relatively minor revisions were adopted, beyond instituting the policy of "buyouts," a substitute for Federal disaster relief payments. G.E. Galloway, Jr., "Floodplain Management: A Present and a 21st Century Imperative," Water Resources Update, No. 97, 4-8, 1994.

It is striking that in a century of evolving public policy the prevailing aim has been to minimize losses from floods and not to optimize the net social benefits from using floodplain resources, including the preservation of the basic associations of soil, vegetation, biota, and water. In simplest terms, it is the contrast between "loss reduction" and "wise use." This shows in the programs authorized, the methods of measuring their value, the organization of studies, and citizen participation.

The benefitting citizens are expected to pay part of the costs of mitigating measures, but public subsidy is expected to offset some of the costs. Some of the costs, including vegetation and soil degradation, and disaster relief, are borne in the long run by society. The latest review of prevailing national toward extreme natural events, such as floods, focuses on the reduction of uneconomic losses and the role of government relief and insurance programs in carrying the burden. R. Platt, et al., Disasters and Democracy, Washington, DC: Island Press, 1999. In that connection, the recent "Second Assessment" review of efforts to deal with disasters, however,
suggests the primary need will be to help foster sustainable or resilient communities in which healthy groups and individuals have reduced their vulnerability to hazard losses as a part of cultivating sustainability.. D. Mileti, Disasters by Design, Washington, DC: Joseph Henry Press, 1999.

The experience with floodplains differs in major respects from that with domestic water supply, but many of the lessons from it are similar.

**Domestic Water Supply and Disposal**

Whereas during the 19th century the evolution of national policy with respect to floodplains in the United States was largely dominated by a few Federal study and construction initiatives in cooperation with local groups, the concern for domestic water use was heavily oriented around local governments and private enterprise that had little part in national development and management programs. Large scale water storage and transport enterprises for irrigation and power were combined in some places, such as California, with meeting domestic water needs, but generally it was the concern of local water districts or private enterprise organized to deliver water to growing areas in conformity with state regulations. Disposal of the resulting waste and its treatment to protect the quality of supply downstream was often a separate concern (although Wolman had pioneered with industrial re-use of waste water). Recently, methods of treating the urban domestic waste have been improved, so that, by thorough recycling through a circular system, it can be re-used safely for agricultural purposes.. Sheaffer, International, Ltd., An Idea Whose Time Has Come, n.d..

The Federal role centered for a long time on the specification through the U.S. Public Health Service and State agencies of water quality standards to apply to the provision of healthy drinking water. Later, it expanded to include concern for the effects of wastewater disposal upon the environment.

States have been sensitive to the protection and granting of water rights for both domestic and agricultural purposes, but have been slow to examine the value of ecosystem services rendered by water and by water effluent volume and quality. The recognition given to the preservation of wetlands under the National Environmental Policy Act has been helpful in that direction. At the same time, little consideration is given to the effect that publically supplied or licensed water may have on urban development or rural ecosystem. An example of departure from that policy is a recent project in reuse of urban waste water in the Shenandoah Valley enables two communities to process their waste so that the effluent meets public standards for human consumption and serves the natural biota admirably.. "System Turns Pollutants into Resources, Runoff Report, Vol. 7, No. 3, 1, 4, 7, 1999. Thereby, the supply and disposal of domestic water can help guide the location and quality of further urban and suburban development.

In contrast to some developing countries where it has been recognized for a long
time that household behavior plays a powerful role in influencing the health of the user, the United States has placed heavy emphasis on the quality of water supplied by public or private enterprises by specifying high standards and by supporting regulation of the pollution of water bodies from point sources. There has been relatively little attention to public education for economical and beneficial use of water in the home so as to reduce consumption and waste and to use the supply efficiently. Pricing is only one approach to influencing use and disposal.

Much of the public involvement in providing water to domestic households has focused on meeting human demand sufficient to maintain standards of health at costs that can be paid by the consumer with or without public subsidy. This tends to ignore the ways in which consumers' use or disposal of water may affect the health of the ecosystem of which the supply and disposal areas are part. Per capita withdrawals in many areas are decreasing, and the Environmental Protection Agency has promoted widespread measures to reduce pollution from point waste discharge.

Although the management of nonpoint pollution was a matter of concern by the Environmental Protection Agency, it received relatively little attention in many areas prior to the National Forum on Non-point Source Pollution initiative in 1993. National Forum on Nonpoint Source Pollution, Water: Taking a New Tack on Nonpoint Water Pollution, Washington, DC: Terrene Institute, 1995. When a series of demonstrations of improved management were launched in selected localities across the nation, and domestic management of water was more closely linked with environmental health.

These problems in approaches to supply, disposal, and water treatment call for revised definitions of domestic water use aims, altered criteria of the value of water, and a more comprehensive approach to both planning and execution of watershed projects. The urban household and the wetland ecosystem are now seen as the joint users and protectors of the same water. Considerations of hygiene in household use are coming to be linked with the health of water body recreation and of wildlife reserves.

A challenging facet is the weight given to public support for improving the techniques of treating the quality of water sources. The technological limits to re-using wastewater seem small in comparison to the widely viewed possibility of desalting saline water. In the views of some observers, were desalting to become both physically and economically practicable the major framework for supply-demand analysis would change radically. The establishment recently of the special institute at Carbondale, IL to promote economic methods of desalination is symptomatic of persistent interest in such efforts around the globe.

As in the case of floodplain use, social aims, value criteria, study methods, and stakeholder organization for water supply present a new integrated challenge to engineers and natural and social scientists.
Looking to the Next Century

The coming year will see the definition and discussion at the global level of a complicated set of appraisals of the prospects for the supply, use, and management of water. These "visions" will appear as reports sponsored by the World Water Council, the Stockholm Global Water Partnership, the Consultative Council on World Water Supply and Sanitation, and various other groups in which numerous U.S. scientists are active. They already are the subject of analysis by committees and individual investigators, and are to be welcomed for the evaluations they trigger on local, national, and regional scales.

One frequent theme in some regions is the prospect that the available supplies will be inadequate at some future time to meet the likely demands for water, and that the challenge will be to deal effectively with prospective shortage without resorting to military force. A closely related theme is that this prospective shortage will require a variety of available technological measures to close the gap. This has been the traditional approach to water problems: estimate future supply; estimate the future need; and determine how to close the gap if it looms. In these estimates the role of ecosystems needs for water and the influence they have on long-term supply rarely has a major role in the analysis.

A modified example of this approach at an international level is to be found in the recent four-academies analysis of the problem of sustainable water supplies for a section of the Middle East. Committee on Sustainable Water Supplies, Water for the Future: The West Bank and Gaza Strip, Israel, and Jordan, Washington, DC: National Research Council, 1999. In that analysis the emphasis is on examining all of society’s options related to future water needs, recognizing the full benefits and costs of known lines of action, the conditions in which they might be pursued, and some of the ways in which they might be changed by further technological and social research. It is not simply an approach of forecasting probable social needs and available supply, and then closing the gap through remedial actions on the basis of existing standards and knowledge. Rather, it attempts to recognize how creative use of existing knowledge combined with inventive research on new knowledge might affect public and private strategies as they affect both social and natural systems. The Middle East report is among the first analyses of international river basins to recognize the provision of ecosystem services as an essential water need along with domestic use. This is a framework that is not frequently applied to problems of resource management, but that may help suggest some fresh perspectives in which future needs are examined.

A less significant example at the national level is the action of the American Water Resources Association last year in designing a part of its annual conference and a post-conference meeting to consider ways of improving the coordination of water resources development and environmental regulations that tend to proceed independently. That recognizes that current Federal and State standards are

To broaden the perspective and sharpen the analysis of such exercises it may be helpful to suggest a few of the lessons from the past century that are relevant to evaluation of approaches to solving the problems of the next.

**Selected Lessons**

At the risk of over generalization and recognizing that the coverage is not comprehensive, a selection of the lessons learned from U.S. experiences in the 1900's may be arranged under four headings that have been used in this analysis.

1. There is strong social resistance to organizing to deal with all related social aims in managing human use of the environment in one coherent program. It has been practicable to organize separate programs for irrigating dry lands or making streams navigable or controlling some floods or promoting forest growth or preserving fish populations or countering severe soil erosion or reducing water pollution. It is very difficult to combine all of those aims in a single program or set of objectives, and the welfare of natural environmental systems is most frequently neglected. Some of the reasons include the specialized competence of administrative agencies, and the limited concerns of the politicians and decision makers in determining the authority and financing of those agencies.

2. A second impeding factor has been the difficulty of agreeing upon criteria that can be applied to the evaluation of each and every element in such programs. Notwithstanding heroic attempts over the years to formulate methods, such as in the Principles and Standards, in which contribution to the net national income is estimated, there remain significant differences in aims and methods in judging the social gains and losses between different programs. For example, there are fundamental distinctions among accepted criteria for estimating the value of preventing crop loss and of preserving a wetland and of promoting a stable urban community in which human interactions are enriching.

The recent reports of the President's Council on Sustainable Development. President’s Council on Sustainable Development, Towards a Sustainable America: Advancing Prosperity Opportunity, and a Healthy Environment for the 21st Century, Washington, DC, 1999 and of the National Research Council's Board on Sustainable Development. National Research Council, Board on Sustainable Development, report in press recommend adoption of the three goals of sustainable development--economic prosperity, environmental health, and social well being and equity--in further evaluation of measures proposed by local, state, and national agencies for social development. They do not specify precisely how these general principles would be applied to particular programs. A few agencies, such as the Corps' Institute of Water Resources, have initiated that process, but the task of determining the
suitability and practicality of such criteria now rests upon the whole public establishment and its research arms. Will they be specified uniformly and consistently in legislation authorizing irrigation, power, flood, and wetland investment? For example, it will be important to see how they are expressed in the diverse construction and study programs authorized in the Water Resources Development Act of 1999 (Public Law 106-53).

3. There still are a paucity of practical examples of how a study of a particular area—whether river basin or landscape or human community—can be organized to take into account this full range of social aims with uniform criteria. The vision of the Tennessee Valley Authority in 1933 was never fully realized in the United States or elsewhere on the globe. Attempts in the United States to establish river basin agencies for genuine coordination of planning efforts were abandoned.

1. The most widespread and innovative interests in water management in the United States and many other nations now center on local "watershed" initiatives that cut across the spatial structures of many water, environmental, or economic organizations. It has been difficult to fashion national legislative policy that brings together effective representatives of all the stakeholder groups. The National Research Council and other organizations sometimes are effective in specifying research needs, but there has been relatively little progress in establishing the administrative framework for truly fruitful spatial studies.

1. To date, there have been pitifully few comprehensive assessments of precisely how the stated aims and values inherent in various water or related regional and local water or environmental programs, such as reduction in withdrawals, have been translated into action and how they have affected the societies involved (the paucity of such post-audits world-wide is reflected in a report in preparation).

27. A first attempt to canvass the small number of post-audits of water management projects around the world is being completed for publication by J.R. Wescoast, Department of Geography, University of Colorado, Boulder, CO. The new International Commission of Large Dams will be evaluating the full effects of large storage projects. It is difficult to find a careful, impartial assessment of how the activities undertaken by public agencies in an area—large or small—have affected the well being of people and of ecosystems.

Taking these lessons into account, it seems evident that the science and technology community needs to address systematically with increasing intensity at least four deficiencies, as illustrated in floodplains and domestic water supply and disposal.

2. There is need to fully recognize and specify the complex social aims that are inherent in managing any one resource or combination of resources. While public policy has evolved slowly to take account of many social and environmental relationships, it largely ignores some of them, particularly at the intersection of social and environmental systems.
3. The criteria used to evaluate such relationships are frequently narrow, and while measures such as flood damage reduction or magnitude of communicable disease are used, they do not evaluate other important benefits and costs for the guidance of public policy. The door is just opening to the task of specifying how current practice can incorporate mutually consistent principles of sustainable development in such evaluations.

4. Notwithstanding continued interest in comprehensive river basin planning and in watershed studies, and promising results from a few examples, there still is no widely accepted national framework for planning and carrying out such studies in suitably delimited areas with responsible participation by representatives of a full range of all concerned stakeholders, including citizens and local, state, and national agencies.

5. After a century of vigorous unfolding activity in studying and managing human interactions with water and other elements of the environment in promising areas the nation continues to lack a program to rigorously appraise the observable results of such efforts in the lives of people and ecosystems.

Severe problems of social organization and process stand in the way of achieving such improvements in each segment of water management. In each there is need for imaginative research to extend the limiting conditions of both organization and knowledge. The time is ripe for a unified effort.

Endnotes

1. A comprehensive account of Wolman’s life and major contributions in the water field is to be found in the fascinating two-volume, 1,200 typewritten page, Abel Wolman: His Life and Philosophy: An Oral History by Walter Hollander, Jr, 1981, privately typed, Chapel Hill, NC.


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