ERRATA -- WRRI REPORT NO. 21

Page ii  Next to last sentence, cross-reference should read (see pages 72-75, 75-83)

Page 17 Last sentence, reference to Burlington Mills should read, "Burlington Mills (Industries) which has become the largest user of synthetic fibers in the world."

Page 18 First sentence, reference to DuPont should read, "and DuPont at Kinston for Dacron."

Page 22 Third figure, caption should read, "Figure 4.3. Relative Wages Paid in Industry Groups."

Page 28 Third sentence, first paragraph, add "polyamides."

Page 29 First sentence, third paragraph, change "response" to "responsive."

Page 30 Delete terminal line.

Page 50 Second sentence, third paragraph, delete.

Page 91 Last sentence, fourth paragraph, delete.
A STUDY OF WATER POLLUTION CONTROL
IN THE TEXTILE INDUSTRY OF NORTH CAROLINA

January, 1970

by

Dale I. Gramley

edited by Milton S. Heath, Jr.

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This study was initiated at the Institute of Government of the University of North Carolina in 1966 and completed in 1968. It was made possible by a grant from the United States Office of Water Resources Research through the Water Resources Research Institute of the University of North Carolina.

The author, Dale Gramley, holds a B.A. degree from Davidson College, a Masters degree in education from the University of North Carolina in Chapel Hill, and is a doctoral candidate in economics at the University of North Carolina in Chapel Hill. In 1968-69 he served as an instructor in economics at the North Carolina State University in Raleigh.

The Gramley study is itself a segment of a larger research project: a comparative analysis of selected state water pollution control programs.* (Study states include North Carolina and five other eastern states.) The larger project involves an investigation of program effectiveness, focusing upon administrative, legal and organizational aspects. Gramley's study was designed to add a further dimension through an economic analysis of the waste treatment practices of a major North Carolina industry, textiles.

As noted by the author, two special analytical problems were encountered in this study. One, the unique characteristics of most individual textile mills and the complexity of the textile industry, makes it difficult to generalize about water pollution abatement in this industry. The other, limited availability of data on water problems and water use costs in the mills studied, makes it difficult to reach meaningful findings and conclusions. These analytical difficulties imposed some limits on the scope of this study.

* Principal investigator: Professor Milton S. Heath, Jr.
The opening chapters of Gramley's report, by way of background, review North Carolina textile history, textile technology and waste treatment processes, and the economics of water pollution control. The heart of the report involves a group of field studies of water use and water pollution control practices in selected North Carolina textile mills. (See pages 65 - 94.) Most of the mills that were investigated have their own independent water supplies and waste treatment facilities, rather than relying upon local public utilities.

The findings of these field studies prompt certain observations -- necessarily tentative because of the limited scope and depth of the field studies -- along the following lines:

1. **Least-cost solutions.** Ideally, the individual plant should proceed toward water quality objectives through least-cost solutions. Where possible, this process should involve an examination of the entire water use and waste management system of the plant, in light of its production processes, in order to determine how water quality objectives can be achieved at the lowest cost. Often, a degree of trial and error or experimenting with alternatives will be necessary.

As these studies show, examples are not lacking of North Carolina textile mills that have effectively applied this "least-cost" approach to fully meet desired water quality objectives with some margin to spare. Case studies "F" and "G" are excellent illustrations of well-planned complex water utilization systems which effectively combine waste treatment measures, waste reduction through process control, and water use management, to achieve all available economies to the plant without sacrificing water quality objectives (see pages ). Beyond this, there are probably numerous instances of thorough, if routine, investigations of waste treatment alternatives exclusively (e.g., case study A).
(2) **Limiting factors.** -- The field studies suggest some factors that may place practical limitations on the application of the least-cost principle. It is apparently because of such factors that many mills simply install whatever waste treatment facilities are required to meet minimum demands of the water pollution control law, without thoroughly examining all of their pollution abatement alternatives.

In the North Carolina textile industry important limiting factors include size of plant, age of plant and relative importance of water system costs. The **small plant** may lack sufficient scale or scope to justify the research expenditures required to fully explore water system-waste management costs. The **older plant**, in order to install an efficient water and waste management system, may have to undergo disproportionately large capital expenditures in reconstructing an outmoded piping system and related fixed facilities. Where **water system costs** are a very **minor part** of total plant investment, the incentive to concentrate on improving the efficiency of this segment of a mill is correspondingly small. Where -- as often is the case in the North Carolina textile industry -- plants are small, and old, and have relatively low water system investment, there are formidable obstacles indeed in the way of a thorough-going application of the least-cost principle to water system and waste management costs.

It may well be that, in many cases of this sort, best results will be obtained by moving directly to waste treatment facilities without intervening analysis or diagnosis of alternative approaches. Where feasible, this waste treatment should be handled by a public facility that can realize economies of scale; otherwise by the mill itself.

A related factor that may restrict opportunities for achieving least-cost solutions is plant location. For example, when a mill is located where
lagoonning or other earthen aeration is not feasible, this may limit the potential economies in waste treatment (see case studies "A" and "B").

(3) Analyzing the Textile Economy. -- This study makes a modest beginning on analyzing the textile economy of North Carolina in terms of its relevance for water quality management. Other significant research on related subjects has recently been completed or is now underway.

Among completed research projects perhaps the most important is an analysis of economic and engineering data on Textile Mill Products, conducted on a nation-wide scale by the Federal Water Pollution Control Administration. (This is one in a series of Industrial Waste Profiles entitled "The Cost of Clean Water.")* This report explores the production processes and waste control problems of the major segments of the textile industry (wool, cotton, and synthetics), and makes projections of the industry's anticipated waste loads and costs of pollution abatement for the next fifteen years. Its estimates are presented where feasible in terms of small, medium and large plants, and of older, prevalent and newer technology. This report and the other Industrial Waste Profiles ought to be useful source documents to the FWPCA in the shaping of national water quality management policy during the next decade. To be of maximum help to state water pollution control agencies in shaping State policy, the Industrial Waste Profiles will require some translation into local terms and some supplementation for industries not covered in the series.

Another economic research project of a different nature that should be analyzed for its possible insights for water quality management in North Carolina is a pending study, not yet completed, on the integration movement within the textile industry, by Dr. Milton S. Heath (Sr.). Studies of this nature, involving the economic structure of an industry, may supply insight into trends of economic development that could be useful in guiding the directions and emphasis of water quality management in the State.

(4) Application of Textile Economy Analysis to Water Quality Management. -- It is generally accepted that most water quality management problems -- indeed most natural resources management problems of any kind -- involve three principal components: scientific or technical, legal or institutional, and economic. Our present day water pollution abatement programs have been developed after considerable attention to their scientific and legal aspects. But at this time little or no economic evaluation or analysis is built into these programs in North Carolina, or indeed, elsewhere. It is quite likely, consequently, that important opportunities for improving water quality management are being missed for failure to adequately take into account the underlying economics of the affected industries. It should be possible to devise strategies for taking better account of economic factors in managing water quality. Factors that should be correlated with water quality management in the textile industry include the economic history and trends of the industry; the technology and economics of various alternatives available for reducing water pollution caused by the industry -- including in-plant process changes, as well as waste treatment, and systems-oriented approaches to water pollution abatement for the industry.

* Professor Emeritus of Economics, University of North Carolina at Chapel Hill.

** For example, if one learns from such a study that the textile industry of the State and region is trending strongly toward vertical (or horizontal) integration and for reasons that seem likely to persist, this might be a signal to the pollution control administrator to devise some special strategies for regulating integrated firms.
One desirable element of these new strategies is the introduction into the state water pollution control program of a body of expertise in economics. Among the possible ways to accomplish this may be the following: first, hiring economists and related professionals in existing pollution control agencies; second, utilizing outside economist-consultants in existing agencies; and third, restructuring existing programs in such a way as to require more extensive input of economics, accounting, and statistical analysis -- as, for example, by remodeling water pollution control programs along the lines of utilities regulation.

(5) The role and effect of State water quality management programs. --

The author sees the State Stream Sanitation Committee as exercising through the 1950's and 1960's a growing influence on the textile mills of North Carolina toward control of water pollution. This influence, initially, acted to supplement inadequate economic motivations for water pollution control, and now, in turn, is being supplemented in some cases by economic motivation.

It seems quite plain that, for much of the North Carolina textile industry, economic motivation is too weak alone to bring about desired water quality enhancement. (See discussion of "limiting factors" above, at pages iii - iv.) If water quality goals are to be reached, some additional or stronger motivation or compulsion seems to be needed in these cases.

The traditional solution of the Stream Sanitation Commission, in its "water pollution control" program, has been to seek through persuasion and an ultimate threat of coercion to bring about pollution abatement primarily by individual plants. Chapters 3 and 4 point to other possible solutions that may merit consideration, either as alternatives to the traditional water pollution control program or to supplement it. One such approach is
a system of financial incentives that is based upon a graduated effluent charge or tax levied on polluters. (Although there has been a tendency in some quarters to view this as a "license to pollute," it need not necessarily be so. Proponents of the effluent charge take the position that the tax schedule can and should be adjusted upward until it reaches the point where it is effectively implementing whatever goals of water quality have been established.) Another such approach is to create regional agencies for water quality management, which could build larger and more efficient treatment facilities than could a number of small concerns or municipalities, and could more systematically consider a range of pollution abatement options (including treatment, in-plant process changes that reduce waste loads, stream flow augmentation, and transportation of wastes for offsite disposal). These proposals come with high recommendations from most economists who have addressed themselves to the subject.

(6) The Importance of Viable State Programs. -- The author stresses the stake of the textile industry in a viable and effective State water pollution control program. If the stability of existing State regulations cannot be relied upon -- for example, because these regulations do not adequately protect important groups of water users -- this may work to the disadvantage of industries that have planned their waste treatment facilities on the strength of the regulations. And, as shown by the recent experience of Fiber Industries in Orange County, even the most conscientious firms may suffer the consequences.

The Fiber Industries experience is recounted in detail below at pages 75 et seq. Very briefly, a proposed site for a large new synthetic finishing plant in Orange County was abandoned by this company in the face of determined opposition by conservationists, downstream research users of the
affected stream, and eventually by university administrations of both Duke University and the University of North Carolina at Chapel Hill. The official university position, expressed only in the late stages of the controversy, pinpointed the most substantial ground of opposition to the Fiber plant site: land use policy objections to the location of a large mill close to the university campus, and to the location of a large "wet" industry in the headwaters of a small stream unsuited to receiving its volume of wastes. During earlier stages of the controversy, however, somewhat exaggerated complaints of potential environmental pollution was a focus of attack on the proposed plant site -- in apparent ignorance of Fiber's sophisticated advanced waste treatment plans for the site, plans that had been enthusiastically approved by the State's water pollution control agency. Thus, one incidental casualty of this controversy was the loss of an opportunity to publicize a "show-place" waste treatment facility as an example of constructive industrial cooperation in water pollution abatement, inevitably impairing the credibility of the pollution control program in the process. Another casualty was the loss of a substantial source of employment for the locality. A highly visible set of local political scars -- the product of a long and divisive intra-community struggle -- was another unhappy residue of the controversy.

* * * * * * * * * *

The lessons of this experience ought to stimulate some soul-searching concerning certain aspects of water pollution control activities and related programs in North Carolina. Two features of the Fiber case speak most loudly. First, the State's water pollution control program achieved an apparent success in stimulating an unusually constructive industrial waste treatment plan, but stumbled over a failure to diagnose a case of
unwise industrial site selection. Neither the State's pollution control agency, its industry hunting office, nor any other State department openly identified or criticized the shortcomings of this choice of site. Second, this omission of the State's responsible agencies was remedied with a vengeance by the conservationist-sparked opposition to the Fiber plant. The instrument of public pressure was used with outstanding success by conservationists. Indeed, the effort proved perhaps too successful, as the momentum once launched became an uncontrolled juggernaut that swept away positive values as well as negative factors.

Some may believe that it is not the business of a State water pollution control agency to concern itself with anything but the technical aspects of water pollution abatement, nor the business of a State industry hunting office to evaluate critically the site preferences of its industrial clients. Others may believe that the highest role and only viable strategy of the conservation movement is to serve as a perennial burr in the saddle of development. Considered individually, each of these positions may have some merit. But collectively their effect is to guarantee a series of conservation vs. development confrontations that may have their moments of glory but produce little lasting progress toward improved environmental quality management.

Several potential solutions to this dilemma come to mind, including:

(a) Leaders of the conservation movement in North Carolina could move to devise more flexible and more effective means of exercising the powers that inhere in the movement. Political action in the name of conservation has proven capable of exerting great force in North Carolina, but the principal weapons now at the disposal of the movement are rather blunt instruments. If conservationists were more involved in the processes of government and had better opportunities to participate in the early phases
of resource and environmental management decisions, they might be able to head off many unwise actions without serious frustration of previous developmental planning or substantial impairment of sunk investments. Leading conservation spokesmen have already recognized this, in supporting ideas such as the proposal of the Conservation and Development Study Commission for a Natural Resources Council, to include conservation-minded citizens as well as State agency representatives, and to be furnished a small staff to plan its activities.

(b) Without further legislation it would be possible for any of several State agencies to blow the whistle on ill-advised industrial site selections. The Division of Commerce and Industry might make it its business to exercise greater selectivity as to site recommendations for new industrial plants. The Department of Water and Air Resources might criticize cases of site selection which it believes will frustrate the objectives of the State Stream Sanitation Act, and in some cases might even refuse a waste discharge permit upon site selection grounds. Or, if both of these agencies find this to be contradictory to their missions, other State agencies might fill the gap. For example, the Consumer Protection Division of the Attorney General's Office, the Wildlife Resources Commission, or the Division of Commercial and Sports Fisheries of the Department of Conservation and Development might take action. The Department of Conservation and Development might also move to create an Office of State Ecologist, as recommended by the Conservation and Development Study Commission in 1967, whose business could include the evaluation of industrial site selection in terms of conservation objectives.

(c) Local governments, hitherto little involved in water pollution abatement or conservation programs, might apply their land use planning and regulation powers toward similar objectives. Some stirrings of interest in the subject have recently begun to appear in populous areas, such as Mecklenburg County.
(d) New legislation might be enacted to deal specifically and comprehensively with these problems, through new regulatory controls vested in either existing or new agencies.

One alternate strategy is now being tested. It is addressed more directly to the particular water quality issue raised by the Fiber case than to finding better ways in general of resolving conflicts of conservation and development objectives.

Under a law enacted by the 1969 General Assembly it was made clear that North Carolina streams may be classified for scientific or research uses. (This law was motivated by an early phase of the Fiber controversy, in which an unsuccessful effort was made to reclassify for bathing the reach of New Hope Creek below the Fiber Orange County site. See pages 75 et seq below). At this writing a proceeding has been initiated requesting the creation of a new scientific-research classification. If this succeeds, efforts will undoubtedly be made to apply the classification to streams such as New Hope Creek. Some material obstacles, both legal and technical, may obstruct this strategy. If a scientific-research classification (or something that achieves its purposes under another name) is created and effectively applied, however, this in itself would eliminate some potential sources of conservation-development conflict.

There may be other and better solutions, but those enumerated above will serve to illustrate the opportunities that are available to help resolve some of the problems in the Fiber Industries case.

Milton S. Heath, Jr.
Associate Director
Institute of Government
January, 1970
CHAPTER I

INTRODUCTION

This is a study of water use practices and water pollution problems in the textile industry of North Carolina, set in the context of a review of the industry's economic history. The examination of the industry's water regime was accomplished by means of a group of case studies of individual plants.

The first three chapters following this introduction deal with textile industry history, technology and economic theory. Chapter 2 reviews the economic history and development of the textile industry in North Carolina, together with information concerning the industry's industrial organization. Chapter 3 contains a brief general analysis of the economics of water pollution abatement. Chapter 4 reviews and summarizes the recent textile literature on waste treatment, textile technology, and textile engineering; articles dealing with economic implications of these subjects are given special emphasis.

Against the backdrop of these introductory materials, Chapter 5 examines the actual water use and water quality management practices of a group of textile mills. The study sample was selected primarily from plants that were not connected with any municipal water system. However, in a few instances the plant investigated either some intake water from a municipal system or discharged some waste water to a municipal treatment system. In the interviews of plant management at these mills particular attention was given to the two major alternatives for abatement of water pollution -- waste treatment facilities, and in-plant process adjustments.
Hopefully, the case studies will serve to provide useful new information on prevailing water use and water quality management practices of textile plants in North Carolina. One finding of the case studies is that abatement of water pollution in these mills is usually the result of one of two factors, or a combination of them: of constraints imposed by public water pollution regulations, or of in-plant process changes undertaken for economic reasons (that is as a by-product of such changes). The case studies also suggest the interrelationships between legal regulations for improvement of water quality, engineering and technological aspects of the textile industry, the economic structure and history of the industry, and the economics of individual plant operation.

Within the compass of this study it was not feasible to analyze these findings intensively. It is hoped, however, that others will be encouraged to pursue their implications at greater length.
CHAPTER 2

AN ECONOMIC HISTORY OF THE NORTH CAROLINA TEXTILE INDUSTRY

This study does not attempt to portray a complete history of the development of the North Carolina textile industry. However, it does appear worthwhile to give a brief account of that history, in order to provide perspective for the economic analysis and case studies that follow.

Initially, it should be made clear that North Carolina textile history must necessarily be described in the context of the development of textiles in the Nation in general and in the South in particular. A great deal of the available literature speaks in terms of the region of the South as against the United States or the region of New England.

A number of companies that have developed into large firms with a multitude of plants and locations, although historically beginning in North Carolina communities, have taken on a regional nature and in some instances a national name. Therefore, even though one may be able to satisfactorily follow early North Carolina textile history into the outset of the twentieth century, the task of documenting the North Carolina textile industry becomes more difficult and of a less personal character after the turn of the century. Size, complexity, and proliferation overtake the historian, tending to replace his documentation with figures and comparisons and mergers and acquisitions and multi-product firms with national or regional distribution and sales forces.

Subject to these qualifications, an effort is made in this chapter to trace the North Carolina history of textiles from its incipient stages to the present.
As early as 1775 Alexander Hamilton wrote that construction of cotton mills in the southern states was not only feasible but inevitable. In that same year the Chowan Committee of Public Safety raised eighty pounds (English money) toward attracting a British trained artisan to introduce new machinery for cloth manufacturing. This idea did not materialize.

After American independence was recognized in 1783, the next decade found the United States economy in a futile experiment in state sovereignty wherein each state promoted only its self-interest.

An immigrant, Christopher Taylor, in 1789 had appealed to the North Carolina legislature for support in the establishment of a textile manufacturing plant. He attempted through operation of a lottery to raise enough money for the establishment of a textile mill in order to spin, weave, and dye cloth. The venture fell through.

Men with capital sought restoration of prosperity through a devotion to agricultural activities rather than venturing into factory building. Also a great deal of production of yarn and cloth in the home slowed movement toward factory establishment. This homespun production in 1810 amounted to 7,376,154 yards, valued at $2,989,140, an amount greater than all New England domestic production at that time. The Revolutionary War had accentuated this volume of homespun production, along with the lack of the State's contact outside of its own sovereignty.

With the temporary end of trade throughout the year of 1808, productive manufacturers were given added incentive. The settlement in the Piedmont and
Appalachian Mountains developed a greater demand for local supply of yarn and cloth. The Moravian settlement at Salem by 1808 had purchased the latest spinning and weaving machinery.

In 1813 citizens of Hillsboro met to organize and establish a cotton and woolen factory. Although civic pride was given credit as an influence in such an organizing attempt, profit really was the basic motive involved. The first mill builders must have seen the advantage created by local merchants’ inability to import cheap British yarns. The local merchant would add a mill to his saw mill and grist mill and then sell the yarn right in the store.

The first permanent mill was that of Michael Schenck of Lincoln County, built in 1813. The mill prospered because no imported yarn competed at this location. It was operated by water power, and the machinery came from Providence, Rhode Island, and from Schenck’s brother-in-law, Mr. Warlick of North Carolina. During the Civil War the mill was destroyed and subsequently never rebuilt.

The Rocky Mount mills were planned in 1817. The oldest mill in the State was built in that year at the Falls of the Tar River in Rocky Mount.

The interest of North Carolina in textile advancement was exemplified by the Fisher Report of 1828, which enumerated the advantages to the State of the more extensive introduction of manufacturing enterprises. The report pointed to savings in transportation of textiles that were manufactured locally. Newspaper editorials pushed the whole textile development throughout the State.

In the months following the Report, five new mills were started, empowered to raise a total of $350,000 in total capital. However, all the money was not raised until the boom years of the middle 1830’s.
Meanwhile, by 1830 the New England textile industry appeared to blossom almost overnight. Industrial expansion was New England's only recourse after the War of 1812, while the South was on the eve of a boom era of cotton planting, which favored exclusively agricultural pursuits. North Carolina, with an area almost as large as that of all New England combined, possessed an infinitely superior soil and climate. As a result, the growth of cotton rather than the manufacture of textiles appeared to offer greater prosperity.

The people of North Carolina were biased toward gaining wealth from the land. In spite of this existing tradition, however, a few mills had continued operations. It was the effects of an agricultural depression that brought North Carolina to a period of active mill building after 1830.

The decade of the 1830's brought the intended establishment of twenty-four new cotton mills, of which twenty actually were built. These twenty were located in eighteen different North Carolina counties.

Water power problems (due to floods or low stream flows), fraud among cotton growers, and lack of local capital made establishment of mills difficult. In addition there was a general lack of experienced management in the South. Cotton manufacturers were faced with poor transportation facilities which complicated marketing of the various textile products.

Such problems caused textile leaders to promote many kinds of in-state improvements, especially involving transportation projects.

By 1838 the cotton mills of Fayetteville had both a local and a national reputation for quality and durability. Meanwhile Alamance County was developing as a mill center, headed by Holt's Alamance Mill. This mill in 1853 introduced the first dyeing operation in the South, with the dyed yarns being woven into what later became the famous "Alamance plaids."
Holt reinvested profits in other textile properties and by the 1870's the Holt family had become the most important manufacturers of textiles in North Carolina.

John Motley Morehead erected the Leaksville Mill in 1838. He promoted manufacturing in North Carolina throughout his life. Other mills were also founded at Salisbury and at Asheboro. The 1830's had left North Carolina well encouraged about its textile future—it now had twenty-five mills. Fayetteville had become the ante-bellum textile center of North Carolina, while the first steam-operated mill was established at Greensboro in 1830. Fifteen of the twenty mills built in the 1830's were built between 1836 and 1840.

In 1840 it was reported that North Carolina had a greater number of factories of different kinds than could be found in all the southern states in 1830.

During the 1845-1850 period nearly two dozen mills were built, largely in the Piedmont area. The Gaston County complex had its beginnings in 1845.

By the early 1850's the North Carolina cotton industry had begun to stabilize itself. As a result of the 1849-50 cotton season, raw cotton prices doubled, which in turn brought greater prosperity to the planter, while it increased hardship for the manufacturer. Agriculture continued to predominate.

When the Civil War began, there were approximately fifty mills operating in North Carolina. These mills carried the main load of supplying the Confederacy during the War. After the War, the equipment was worn out and obsolete. Manufacturing interests faced the tax problem and money-value uncertainties by inaugurating stock purchases by citizens. Communities everywhere tried to get in the act of promoting a mill.
By 1860 the textile industry began to build forward momentum, and by 1885 there were eighty plants in North Carolina, totaling 196,000 spindles, 3,000 looms, and 7,500 North Carolinian employees.

By 1890, mills were immense in size when compared to the pre-Civil War ones. There existed 115 mills, with approximately 500,000 spindles and 20,000 looms, and a capital investment of $10,000,000. The largest mill in the state was Odell Manufacturing Company of Concord, formerly Concord Manufacturing Company (20,000 spindles and 851 looms).

E. M. Holt, of Alamance County textile prominence, died in 1884. He had become the richest man in North Carolina, owning eleven mills valued at $1,100,000 (36,460 spindles and 1,978 looms).

In 1890 forty-four of the North Carolina mills either belonged to pre-Civil War concerns or were mills established prior to 1860. Pre-war mills were smaller, less efficient, and often equipped with antiquated machinery, when contrasted to post-war mills.

By way of comparison to the Holt holdings, in 1894 there was a textile worth of some $26,000,000 employing 25,000 workers, and operating 650,000 spindles with 30,000 looms. Knit hosiery and underwear had been introduced into the textile production assortment.

The South was emerging as a new competitor unburdened with investments in out-moded machinery. The region was beginning to install new machinery practices, while the New England manufacturers felt that the southern employment practices coinciding with New England social legislation were cutting the New England market to shreds.

By the end of the nineteenth century there were over 400 mills housing more than 4,000,000 spindles and over 100,000 looms. By 1900 the textile industry in the United States had witnessed a shift in regional location, a mechanical over-
haul, influx of investment capital and a widening of domestic and foreign markets, plus alterations in fashions demanded by the consumer. North Carolina was in the middle of the ongoing transformation.

The feeling in the North that southern competition would become so strong and assertive as to endanger the stability and future prospects of the cotton industry in that section was made even more real or intensified by intermittent business depressions.

The depression of the mid-1890's had given evidence of the need for textile to diversify their products, as seen in expansion of knit goods. P. H. Hanes in 1901 built his first underwear plant near Winston-Salem. James W. Cannon introduced the terry towel at his Kannapolis mill. (By 1965 this mill complex employed approximately 20,000 persons.)

In 1902 John Gant founded the Glen Raven Mills, largest maker today of outdoor awning and textile fabric. The Holt family meanwhile brought William A. Erwin into the textile business at the Alamance mills. Erwin later worked for Benjamin Duke, founding the Erwin Mills around Durham. T. M. Holt and relatives got Moses and Caesar Cone to establish Cone Exporting Company in the 1890's, which later became Cone Mills.

The primary deterrent to the health of southern industrial stability came in the redundancy of cotton mills inadequately financed and amateurishly staffed. The competition that took place under such circumstances brought negative results. Cotton mills had been looked upon as a panacea for the rural poor and as a moral revival for southern communities.

Prior to 1900 textile demand had been high due to the increased population. In 1800 there were five million persons as against seventy-six million by 1900.
The per capita real income of employees had also risen. The increased efficiency in production had reduced the cost per unit of production, thereby allowing a positive reaction on demand due to its high elasticity, or response to lower prices. Also, because textiles is a labor intensive industry, the distribution of income within the economy was facilitated, and therefore the welfare of the population in terms of buying power.

In the first decade of the Twentieth Century new productive capacity in the South accounted for seventy per cent of all new productive capacity for the entire textile industry. The industry had been helped via the ring spindle replacing the old mule spinning method. This innovation required less skill by the operator than previously had been needed. The industry had been further aided with the introduction of the Draper automatic loom, around 1900.

The attraction of textile production to the southern labor market was not hindered by the fact that by 1900 the northern wage rate was supposedly twice that of the South's for coarse and medium quality manufacturers (sheetings, shirtings, duck, drills, ticks, denims, and yarn.) Besides, southern public opinion was against use of labor organization for such aims as higher wage rates. The South had developed too far with its paternalistic policies which dominated the southern mill villages. These village set-ups actually reduced the monetary differential in the wage rates that were referred to previously.

The industry grew from 145 mills in 1895 to 281 mills in 1910. In 1910 there were 2,958,235 spindles, with 56,000 looms, and consumption of 754,483 bales of cotton. This cotton went into the manufacture of yarns, sheetings, shirting, upholstery fabrics, hosiery, etc., valued at $72,680,000.
After 1910 the character of North Carolina textile products shifted rapidly to finer grades of manufacturers. Problems of labor and education entered as needed improvements to go along with the progress of the textile industry.

By 1920, slightly better than half of the spinning and weaving capacity of the industry was located in the South. Today the South has approximately ninety per cent of spinning capacity, while in 1940 it had around eighty per cent of the spinning and weaving capacity.

It should be noted that New England employment in textiles did not fall as rapidly as often thought. This may be noted because New England mills shifted to two and three shift operations by World War I and because weaving and finishing capacity did not move to the South as soon or as rapidly as spinning had moved.

Following World War I, however, New England went back to one shift primarily, while the South stayed on two shifts. The South could do this since there was no social legislation enacted in the South, while the New England states had already enacted such legislation. Also New England had to keep higher wages in order to compete with other manufacturing enterprises, while the South competed basically with farm wages.

Further benefit accrued to southern textile growth besides installation of new equipment as new mills were established. The additional benefit occurred as northern machinery producers changed policies which initiated extended payments over longer periods of time. This gave the South an incentive to expand. In addition, the South received financial assistance from northern commission houses. This action helped assure supply of textile products coming to commission houses for them to handle.
Naturally such a developing relationship as that between commission houses and textile mills aided the movement toward vertical integration that evolved in later years. The longer-term machinery purchase contracts plus commission house arrangements had not been available to the older established industry of New England. Therefore, the short-run and long-run costs to southern textile mills tended to be lower.

World War I did bring profits resulting from healthy war demands, but the 1920's were generally profitless, as the textile industry did not share in the general prosperity of the nation. Meanwhile, by 1923 North Carolina had twenty percent of textile employment in the South. In 1923 there were approximately five and one-half million spindles, 77,000 looms, and employment of 158,000 persons, with products valued over $300 million annually. It was in 1923 that southern mills first exceeded the New England mills in total mill production.

The North's losing battle is indicated by the fact that the number of total spindles changed from approximately twenty million in New England in the early 1920's to around five million by 1940. Meanwhile the South went from approximately seventeen million in early 1920's to approximately eighteen million spindles in 1940.

The industry was faced with excess capacity due to new equipment, extension of running time, and decrease in demand for cotton goods. The industry had to bear the burden of funded debt, outside bank loans, padded inventories and lack of proper maintenance. In fact the number of United States spindles declined from thirty-eight million in 1925 to twenty-six million in 1939.

The heyday of trusts had brought some mergers, yet profits of the industry were small and mills went bankrupt. In addition rayon came into production,
hurting cotton demand. The merger move was not great due to variety of products and individualism of owners. Not until World War II did mergers and acquisitions take place in a significant manner.

Cotton and wool of course have been the traditional textile fibers. However, both fibers have accounted for a decreasing share of total fiber used by the textile industry. A result has been that many cotton textile plants have adapted to rayon and other synthetics. This makes it more difficult to draw a sharp definition of cotton textiles as a single industry. A leader in cotton textiles can at the same time be a major producer of some synthetic or blended fabric.

In 1928, North Carolina had four hundred twenty-nine cotton mills with 6.1 million spindles and 88,000 looms. The cotton mills plus rayon and hosiery mills employed 102,000 people. In 1933 North Carolina surpassed all other states in the number of spindles in place.

Rayon had actually been introduced for production in Virginia as early as 1910, and by 1915 its production was seventy per cent in the form of hosiery and lingerie. It was not until 1936 that rayon was developed for use in tire production.

In 1923 Burlington Mills started with rayon production and 200 looms. This start was just prior to the depressing times for textiles which had hit in 1924. Through efforts of James Spencer Love, Burlington managed to hang-on through numerous purchases, sales, mergers, and other financial arrangements. Burlington stuck almost entirely with rayon production. By 1949 Burlington was one of the country's largest hosiery manufacturers. And by 1955 Burlington had nine different divisions of manufacturers, with 20,000 looms and over seventy plants, with full integration of their production. Burlington had entered
into more mergers and purchases than any other company in textiles.

By 1930 the textile industry had recognized the need to vertically integrate in order to co-ordinate sales and to control production. The over-production of the industry and subsequent existence of marginal firms encouraged "scalping" at bargain prices by those companies in good financial condition. Marginal firms would be bought and the machines put into running production anyway. This continued the over-production while at the same time the purchasing firms had the advantage of picking up the machinery at reduced costs.

By 1939 the recovery of textile product demand from the lag of the 1920's was established. There existed three hundred eighty-one mill company names (one or more mills), with complex products and fibers involved. This represented 120,000 jobs, which was fewer than in 1923 (just prior to the textile depression), due to better machinery and training of workers. Paternalism of the past was disappearing, while self-respect was being attained. The 1939 value of cotton products had reached $177,367,000 and value of textile products had come to around half a billion dollars.

Research and development began to receive attention, as shown by the recognition gained through the North Carolina State Textile School. Meanwhile more plants joined the North Carolina Manufacturers Association.

World War II obviously increased the demand for textile products. The Office of Price Administration with its program of price stabilization and profit allowance policy was a major factor influencing integration and merger within the textile industry.

For example, between 1940 and 1946, one hundred sixty-four cotton textile companies had reported changing hands. This represented 4.4 million spindles.
and approximately 80,000 looms—about twenty per cent of the industry's productive facilities. Approximately half of these changes were vertical acquisitions, involving either selling agents or converters.

Between 1943 and 1948 the ownership of two hundred eleven southern mills changed hands, involving almost 5 million spindles and 90,000 looms. Competing firms bought out their opposition. By 1947 vertical integration resulted in thirty-three per cent of all cotton firms (more than one plant) listed in Moody's Industrials becoming fully integrated. Almost seventy-five per cent began acting as their own selling agent. By contrast, in 1930 only ten per cent of firms were fully integrated and forty-three per cent had their own selling agent.

Synthetics appeared in increasing numbers and varieties, as research and development of chemistry took fruition much beyond the earlier rayon inroad. The fibers were marketed under specific brand names and advertised accordingly. The industry had become market or consumer oriented. The preceding vertical integration had made such a pattern feasible.

Vertical integration had also made the industry more concentrated. Consumer preference had likewise become a more dominant part in determining the products under production.

In weaving capacity of southern plants, such capacity increased an average of 5.6 per cent, while North Carolina led with an increase of 9.8 per cent in number of looms, from 1945-1950. In spite of this increase of percentage and number of wide looms (numbering 19,784), the number of looms for the whole country decreased—reflecting increase in the South while the North reflected a decrease. However, it should be noted that greater poundage came off the fewer looms due to increased speed of new looms and therefore increased production per
loom, which more than compensated for total numerical decrease in number of looms during this period.

Once backlog orders were filled following World War II profit margins decreased for the industry, and the World War II merger-rush subsided. Many of the mergers that had taken place among the small mills and small converters were liquidated. At the same time the larger more successful firms continued to add to their facilities as consumer followings, quality control within their organization, and product differentiation maintained a healthy trend.

Barkin of the Textile Worker's Union of America noted in 1955 that 43 interests in the spinning, weaving, and finishing divisions of the industry owned 507 plants that employed 345,000 persons out of a total of 656,000 production workers in the industry.

Product mix in the industry as of 1965 showed that synthetics accounted for forty-three per cent of all fiber used in the United States in 1965. This figure was up from twenty-nine per cent in 1960 and is expected to reach 50 per cent by 1970.

In 1952 the total value of all textile products in North Carolina production came to $2.9 billion, or forty-five per cent of value of all North Carolina industrial products. This production was accomplished at approximately 1,100 mills, by 234,000 employees, or fifty-two per cent of all North Carolina industrial employees.

North Carolina has 6.1 million or twenty-seven per cent of the United States total spindles; 434 knitting plants, and produced forty per cent of United States hosiery at that time. Figures show production of textiles at twenty-two per cent synthetics, seventy per cent cotton, and eight per cent wool, in 1952. By 1960 this percentage breakdown was twenty-nine, sixty-five,
and six per cent, respectively. By 1965 this breakdown was forty-three per cent for synthetics, fifty-two per cent for cotton, and five per cent wool. The increase in the efficiency of machinery plus going to two and three shifts has changed the basis for comparing the number of spindles between years. The bias created underestimates today's figures. Therefore, the effects of technology on per cent figures can only be estimated.

From 1930 to 1950 construction of new spinning and weaving cotton mills was just about non-existent. Construction from 1946-49 was mainly in finishing plants and hosiery mills. From the close of World War II through 1951, North Carolina had great textile growth. The 1951 figures showed 1,047 plants in North Carolina (thirteen per cent of all North Carolina industrial plants), 230,000 employees (fifty-four per cent of total North Carolina industrial employees) and forty-four per cent of all sales of North Carolina manufactured goods. In 1939 there had been only 695 plants, with 180,000 employees, and thirty-nine per cent of total value of production.

The center of the North Carolina textile industry had moved from its historic eastern beginnings at the edge of the Piedmont, to Gaston County in the western Piedmont. Gaston County in 1960 had 130 mills and employed approximately 50,000 workers.

Some of the primary leaders in the textile industry today are: Cannon Mills of Kannapolis; Burlington Mills (Industries) which has become the largest producer of synthetic fibers in the world; Cone Mills at Greensboro, known for flannels and denims; multi-product Erwin Mills at Durham; Textiles, Incorporated of Gastonia; American and Efird Mills of Mt. Holly; J. P. Stevens with a number of plants in North Carolina; North Carolina Finishing Plant of Salisbury; P. H. Hanes at Winston-Salem; Chatham Manufacturing of Elkin, noted
for its blankets; Fieldcrest Mills at Leaksville-Spray; American Thread, outside of Marion; American Enka at Asheville, with rayon; and Du Pont at Kinston.

Some of these company names resulted from family beginnings in the nineteenth century strictly within the borders of North Carolina. However, with the evolving structural change and growth of the industry, today it is unusual to find any of these companies with plants only in North Carolina.

Perhaps this brief glimpse at the North Carolina experience in particular and the development of textiles in general has given some insight into the growth of the textile industry.

There is no doubt that textiles lead the industrial economy of North Carolina. There are approximately 1200 different establishments in the state and employment comes to around 44 per cent of the North Carolina manufacturing labor force. None of the other industry groups employs one-fifth as many workers.

When looking at the total industry, there exist divisions of the industry that are more like industries within themselves. Although this study emphasizes the wet-processing side of the textile giant under the classification of Finishing Plants, all of the percentage distributions are given below. These figures are taken from the 1963 Census of Manufactures and the Atlas of North Carolina.

<table>
<thead>
<tr>
<th>North Carolina Textile Industry</th>
<th>(Percentage Distribution)</th>
<th>Employees</th>
<th>Value Added</th>
</tr>
</thead>
<tbody>
<tr>
<td>Broad Woven, Cotton</td>
<td>23.0</td>
<td>22.0</td>
<td></td>
</tr>
<tr>
<td>Hosiery</td>
<td>24.5</td>
<td>20.0</td>
<td></td>
</tr>
<tr>
<td>Sales Yarn, except Wool</td>
<td>17.6</td>
<td>16.0</td>
<td></td>
</tr>
<tr>
<td>Broad Woven, Synthetics</td>
<td>14.2</td>
<td>16.4</td>
<td></td>
</tr>
</tbody>
</table>
This textile production takes place primarily in the Piedmont region of North Carolina. This region lies between the Mountain subregion comprising 17 counties and the Coastal Plains subregion which comprises 41 of the 100 North Carolina counties. Eighty of the one hundred counties have textile operations. However, some twenty counties in the Piedmont subregion account for eighty per cent of the state's textile employment and production facilities. Five of these twenty counties account for forty per cent. There are thirty counties that account for only three per cent of the total textile contribution. This means that out of the 100 North Carolina counties, fifty account for little or no textile involvement.

The Piedmont region is also the primary manufacturing center for the state, besides accounting for 52 per cent of the population in 1960. Thirty-four per cent of the population in 1960 lived in the Coastal Plains region.

The Piedmont has economic advantages that the other two subregions do not possess in the same abundance. Historically, the Piedmont had hand spinning and weaving as a principal industry prior to factories. Besides this tradition, cheap and abundant supplies of water power and labor were available. Cotton was grown in the vicinity and therefore easily accessible. The topography also made manufacturing a more natural pursuit for this region than agriculture,
which was more conducive to the flatter Coastal Plains region. As a result, railroads were advocated in the Piedmont, plus the location of early mills along such railroad routes. This early pattern, though transformed, still basically remains a part of the transportation system of the Piedmont.

With the establishment of the Piedmont as the industrial center of North Carolina, it has been more difficult for industry to disperse itself into other areas of the state. General economies resulting from concentration of industry in the area make it easier to locate near centers of concentration or immediate outlying districts.

The following graphs taken from the April-May, 1966, Textile Forum (a publication of the School of Textiles, North Carolina State University) give additional insight into county-by-county distributions with respect to concentrations of manufacturing employment, population, textile and apparel manufacturing employment, and for non-agricultural employment in North Carolina:
NORTH CAROLINA EMPLOYMENT BY COUNTIES, 1960

Figure 3.2. Comparative population concentrations in North Carolina on a county-by-county basis

Figure 3.3. Comparative concentrations of nonagricultural employment in North Carolina on a county-by-county basis

Figure 3.4. Comparative concentrations of manufacturing employment in North Carolina on a county-by-county basis

Figure 3.5. Comparative concentrations of textile and apparel manufacturing employment in North Carolina on a county-by-county basis

TOTAL MANUFACTURING EMPLOYMENT INCREMENTS

- UP TO 3,000
- 3,000 TO 6,000
- 6,000 TO 9,000
- 10,000 TO 18,000
- OVER 24,000

TOTAL POPULATION INCREMENTS

- UP TO 25,000
- 25,000 TO 50,000
- 50,000 TO 75,000
- 125,000 TO 150,000
- OVER 200,000

TEXTILE AND APPAREL MANUFACTURING EMPLOYMENT INCREMENTS

- UP TO 1,500
- 1,500 TO 3,000
- 3,000 TO 4,500
- 7,500 TO 9,000
- OVER 12,000

TOTAL NONAGRICULTURAL EMPLOYMENT INCREMENTS

- UP TO 4,000
- 4,000 TO 8,000
- 8,000 TO 12,000
- 16,000 TO 20,000
- OVER 32,000

Malcolm and Apparel Manufacturing Employment Increments

- UP TO 1,500
- 1,500 TO 3,000
- 3,000 TO 4,500
- 7,500 TO 9,000
- OVER 12,000
Figure 4.1. Comparison of employment in the five leading industry groups in North Carolina from 1959 to 1963

Figure 4.2. Relative percentages of manufacturing employment in the five leading industry groups from 1959 to 1963

Figure 4.4. Relative percentages of manufacturing wages paid by the five leading industry groups in North Carolina from 1959 to 1963
In 1960, fifty-one per cent of the 507,330 workers employed in all North Carolina manufacturing were within the area of textiles and apparels. Of North Carolina's total employment in textiles and apparels, eighty-four per cent was in the Piedmont region, according to the Employment Security Commission figures for that year. The heaviest employing counties for the textile and apparel industry were Gaston, Guilford, Cabarrus, and Alamance; other counties of high employment were Forsyth, Randolph, Catawba, Mecklenburg, and Rockingham counties.

From 1960-1963 this industry maintained close to fifty per cent of all manufacturing employment in North Carolina. The other industries in order of employment were furniture, tobacco, food, and lumber. Textiles and apparel had more than five times the employment of furniture, and more than eight times the number of employees in tobacco. Textiles and apparel had similar dominance with respect to wages paid (not meaning per capita wage, but total).

The textile and apparel industry employed approximately sixteen per cent of the civilian labor force in 1963, while employment in wholesale and retail trade represented about fourteen per cent. Government employment followed, with eleven per cent of the employment.

In terms of national figures, North Carolina leads the nation in textiles. The state accounts for approximately twenty-nine per cent of all textile employees and twenty-eight per cent of value-added, for the 1963 compilation of figures. North Carolina's leadership is impressive especially with regard to sales yarn (other than wool), where the state manufactures almost two-thirds of that product. It also accounts for fifty-eight per cent of the hosiery and thirty six per cent of the synthetic fabrics.
The percentages for other classifications of production in textiles in terms of the nation were as follows: knitted underwear, twenty-five per cent; thread, estimated at twenty-five per cent; broad-woven cottons, at twenty-one per cent; knitted fabrics, twenty per cent; finishing, fourteen per cent; and narrow fabrics, twelve per cent.

During the decade prior to 1958, the state's lead was reported to stay around twenty-three per cent; since then it has been increasing.

Diversification has become a significant trend. Such trends have taken place in the branches of carpets and rugs, wool fabrics, knitted goods, threads and the finishing of synthetics, the development of blended yarns and fabrics, plus a broadening of product mixes in the older broad woven and sale yarn groups.

In addition, the Atlas of North Carolina reports that growth rates have been highest in knitted goods, synthetics and finishing, where market demand has been the greatest. These rates have been considerably above national growth rates. The North Carolina growth rate for finishing has been twice as high as that of the national rate, while knitted goods have enjoyed a rate three times as high as the national one.

On the other hand, the state growth rate for cordage and twine has declined even more so than the national rate, which also has been declining. The evidence points to a shift in North Carolina from divisions of lower productivity to those of higher. The North Carolina productivity in its textile operations has increased more rapidly than the national average. New capital expenditures in recent years has been largely accountable for this development. In 1963 the state's new capital expenditures were thirty-nine per cent of the national total for the entire textile industry.

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While the figures given indicate the nature of growth taking place in the industry and over the region or nation, such historical accounting of the development of textiles necessitates some additional remarks that lead more directly into the processing and technological implications of this study. A brief accounting follows, at the risk of later repetition, of more detailed textile operations and some broad developments over the industry.

The transformations within the industry in the more recent years indicate that the tendency is toward multi-unit integration. This increase in integration of operations has tended to concentrate toward the top ten firms. For example, in 1936 approximately fifteen per cent of the industry spindles were located in the top ten firms, while in 1958 approximately fifty per cent of the spindles were owned by those firms. The single unit operation had become part of the multi-unit firm type of ownership.

For example, a large firm is likely to have numerous divisions under it, each with its own trade name. The large firm can put orders for certain type goods into one plant. In this way a particular plant becomes more economical to operate. At the same time this does not necessitate a gigantic plant attempting to gain economies of scale under one roof. The net result appears to be specialized plants in a variety of sizes.

In addition to the multi-unit integration within large companies, integration in operations has also taken place. Where previously a firm was involved in spinning and weaving operations (as New England firms previously were), spinning, weaving and finishing are now integrated into the full plant operation. This trend became significant at the end of the last decade.

In essence, there has taken place a marked increase in the size of firms, which represents a higher degree of concentration. And secondly, the trend has turned toward vertical integration of plant operations—to
absorbing finishing and selling house operations and converting, in some areas.

However, this description does not mean complete integration by all. There are many plants that "take in one another's wash" due to locations, convenience, and accessibility of the "small man" being able to set up a textile operation not based on economies of scale. That is, the size of a mill is enlarged by adding machines and not by increasing the size of the machine itself. The labor that increases with size of plants increases approximately in proportion to the number of machines. Therefore, many small mills continue to operate, do specialty supplying, etc., where the big mill does not wish to deal in certain styles or whatever.

Diversification also enters into the consideration of integration. No longer do most firms concentrate their production into one standard product as done in earlier days. For example, Cannon into towels, Cone into gingham and corduroy, did this sort of concentration. Early consolidation had been more horizontal in nature and therefore more concentrated into a particular line of product. At the same time, it can be stated that firms are not exempted from such concentrations into a single line. Cannon Mills continues to do a great deal of towel production.

It does appear that textile production now takes place either within the large firm or else within the small plant of operation. Before this development there had been a large intermediate group. This group has largely disappeared from the industry.

Meanwhile, finishing operations have shown a tendency to locate in South Carolina, where large grey goods mills require a large amount of bleaching, sanforizing, etc. In some degree of contrast North Carolina production is more diversified. One extreme example is sales yarn located in North Carolina, while
South Carolina has virtually none of this. South Carolina is big on broad-woven fabric and therefore finishing.

Textile production in more detail is involved with such operations as spinning fiber into yarn, either weaving, knitting, or braiding the yarn into cloth, or finishing the yarn directly into thread, cordage, or twine. The manufacturer does spinning, spinning and weaving, weaving, knitting, braiding, and/or finishing. There exists a tremendous complexity of differentiation within this whole context of consideration. Woven goods comprise broad woven into many designs and with numerous grades of material; besides, the same applies to narrow woven as well. Then there are knitted products such as hosiery, outerwear, and underwear. And once again, a great deal of differentiation is involved here too.

Finishing grew up as a separate operation not suited to integration with spinning and weaving operations. As a result, finishing (dyeing, bleaching, printing, calendaring, etc.) became a separate industry.

Grey goods are cotton fabrics that have been processed from yarn but have not been dyed, bleached or mercerized, or further finished before being readied for use.

Most of the basic technology of the production operations had been invented by 1860 so that improvements only resulted thereafter. For example, the Northrup automatic loom was an advancement in efficiency of weaving, while at the same time it was an innovation only. The real revolution in the industry took place in the machines and their increased efficiency and refinement. This led the way for expansion of the industry. In fact just in the last few years many changes in machinery investment have taken place in the textile industry, as such expenditures have become of prime importance to the competitive ability of
textiles, with its tradition of heavy employment of labor.

In the man-made fibers development two classes of synthetics have arisen in this area: cellulosics, which use woodpulp as a basic source of cellulose; and synthetics, which use derivatives of coal tar, petroleum, and natural gas. Examples of methods of producing cellulosic fibers are the viscose and acetate processes. Examples of new synthetics are acrylics, polyesters, olefins, and polyvinyls.

The 1920's evidenced a rapid growth in the production of cellulosics, rayon, and acetate. The 1940's showed a rise in the synthetics, especially nylon. And since that period, the new synthetics, acrylics, polyesters, etc., have grown in production. Nylon pushed out rayon and acetates to a considerable extent in the 1950's.

As a result of this development, a whole new branch of the chemical industry has grown out of man-made fibers. A scientific basis and research orientation have become very important to a definition of this aspect of the textile industry.

In the finishing operation, and therefore the majority impact of the wet-processing and waste effluent problem in the industry, the surface characteristics of the material are the prime consideration. Quality, feel, color, stability, and appearance are some of the main points of reference toward achieving desired results from this operation.

The finishing operation is a heterogeneous one when compared to the simple mechanical operations of weaving and spinning, as diverse specifications are involved throughout finishing. Some finishing operations are applied to all textile products, while other operations are only applied to parts of the production involved.
In many cases the dyeing, bleaching, and mercerizing wet-processes are combined with the spinning, weaving, or knitting operations—as in many grey goods mills. Any of the final finishing processes such as scouring, sanforizing, treating, calendaring, or water-proofing may be applied to the fabric after it has been woven. There are a multitude of operations that can be applied to the final finishing quality of the fabric.

Dyeing commonly is done between spinning and weaving or knitting, although the sequences can be altered just as well.

Innovations in finishing are response mainly to changes in other segments of the production processes or from outside—as from man-made fibers or research in color and dyes.

The primary technological changes in finishing have been in dyes and dye methods, alterations in the fabric characteristics, and through continuous process operations. Additional problems have flowed from the resistance of synthetics to dyes, which required methods for forcing the dyes into the fibers and for more lasting effect of dyes in the material. Human skill is a factor in obtaining the desired results.

It is important to this study that the ongoing developments be studied with respect to their impact on water-related considerations.
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CHAPTER 3

THE GENERAL ECONOMIC RATIONALE OF WATER POLLUTION ABATEMENT

The Perfect Competition Model

A great deal of economic theory is concerned with the functioning of the market mechanism, as the economic forces of demand and supply act under price signals that determine consumer behavior. Such theory often uses the perfect competition model to describe this behavior of the market-place, although other market models may fit when conditions of imperfect competition prevail.

Of course the perfect competition model rarely makes a precise fit with the real world, due to its many assumptions about the world. These assumptions are necessary in order to describe the ideal behavior of prices and markets. In the perfect competitive market buyers and sellers do not exploit one another since each factor of production ideally receives the value of what it has produced. The product commands a price just sufficient to pay those factors of production. As a result, all consumers buy products at prices reflecting the true costs of their production. All of the "play" of the market is in terms of a private market without any consideration of factors other than the effect of the price mechanism on supply and demand. That is, no consideration is given to any social costs or social benefits that might result from the action of the private market.

Another important feature of traditional economic theory is the marginal cost pricing principle. Under this principle of market action, the marginal cost of each additional unit of output by the firm is
equated to the marginal revenue received by the firm for that additional output. By following this principle, it is posited, the greatest efficiency in production is obtained. Costs per unit of production are minimized and thereby minimum prices to the consumer are achieved. The firm produces to that point where all costs are just covered by the revenues received.

Theoretically all firms come to this point in their trade-offs among the opportunities of production facing them. Each firm chooses those opportunity costs that minimize costs in terms of the production involved. If one set of costs theoretically is not a minimum, then the firm is not operating at optimum economic efficiency. To achieve optimum efficiency the firm will "trade off" until it reaches that set of costs that bring optimum efficiency.

The Problem of External Diseconomies

Like the perfect competitive market model, the theory of marginal cost pricing does not give a total account of reality. Perfect competition and marginal economics fail to account for one problem that is basic to the water quality regime, the problem of external diseconomies or spillover costs. Inherently, the damaging effects of water pollution are usually not felt by the person or firm causing this condition. In this sense, these effects are "external" to the polluter, and they "spill over" to other firms and persons. Because of this, costs which should be internal to the firm may be passed along to others. This produces a diseconomy in the form of a subsidy to the polluter who should bear the real cost of treating or reducing his own wastes. These diseconomies are translated into a social expense left for society to bear.
The depositing of polluted effluent into receiving streams represents a prime example of the private market price system not accounting for all of the true costs of a business. As a result, price only reflects private costs. The demand and supply pressures working on the good produced do not cover the pollution costs created. The value of the products does not reflect the full cost of producing it.

Weisbrod has aptly expressed this economic problem:

Classic examples of external real diseconomies are air and water pollution -- 'external' because the effects are borne by persons and firms other than those who cause the pollution, 'real' because production and consumption opportunities elsewhere in the economy are reduced, since polluted water is a detriment to other users of water, whether for business purposes, or for drinking or swimming . . . so we see total production or consumption possibilities altered; 'pecuniary' effects come via changes in relative prices without affecting total production or consumption -- only redistribution of goods and services among the people.

While the private firm seeks efficient resource allocation according to the preferences of consumers, the deposit of polluted effluent into receiving streams does not lead to a maximization of society's welfare. Technological interdependency such as upstream waste disposal causing downstream damages precludes the equilibrating of individual and social welfare simultaneously.

Since industry has not had to pay these external costs, industry costs have been underestimated. Therefore, in theory, a greater production develops because the firm's marginal cost curve is lower than it might otherwise be, due to its inclusion only of the private costs of the firm.
This leads to over-allocation of resources. Or stated another way, this is an indirect subsidy-service to those firms. Therefore, the marginal firm is over-extended in the sense that firms have a greater capacity than justified. This has been accomplished at social expense due to the factor of external diseconomy.

Solutions to the Problem of External Costs of Water Pollution

In economic terms, water pollution problems are resolved by dealing with the external diseconomies that are created by polluters. Sometimes, of course, organic pollution may be completely oxidized after being in the stream channel for a relatively short distance, such that external effects involve no significant economic consequences. Sometimes the affected private interests can resolve their own water pollution controversies without public intervention. More often, though, the answer must be found in public policy. Where externalities are at the root of an issue, public intervention usually proves necessary to achieve an effective solution. It should come as no surprise that traditional private law concepts and processes are no better able than traditional economies to cope with externalities. Moreover, water is a "social good" in the sense that it must be used and reused by many persons; this, too, weighs the balance in favor of governmental solutions to water quality problems.*

* The statement that water is a "social good" should be qualified by noting that there are private property rights in the use of water. While the use of a stream for pollution abatement has never been accorded the status of a private property right, the privilege of causing a reasonable degree of impairment in water quality through use has generally been given at least grudging recognition under water rights doctrines. Without getting involved in details, suffice it to say that this legal factor requires some consideration in the formulation of public policy concerning water pollution. Economists will find this quite rational, since waste disposal may be a productive use of water resources in some circumstances. To the degree that it is less costly than other alternative courses of action, waste disposal may save resources and foster greater production and consumption.

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Public water pollution policy traditionally has taken the form of regulations concerning disposal of untreated wastes, emphasizing the public character of the use of streams. In time the regulations have been supplemented by financial subsidies to help meet the imposed expense of water pollution abatement. Thus, typically, the answers of public policy to the problem of externalities has been to require the polluter to relieve downstream water users from the burden of external costs, and then to help (at least some) polluters to finance these costs. One of the shortcomings of the regulatory solution is that it pits the public pollution control agency against the polluting firm in terms of the strength of the law and its enforcement as against the economic cost alternatives faced by the firm. Pressures can build upon state and local agencies from those who must comply with the laws. Whenever financial sacrifice is involved, enforcement of regulation becomes difficult; in the usual experience of regulatory agencies, it becomes increasingly difficult as time goes by.

In recent years economists, notably Dr. Allen Kneese of Resources for the Future, have argued for two remedies that they suggest will attack the cause rather than the results of water pollution, by "internalizing the damaging effects of pollution." One solution is to create regional agencies for water quality management whose broad territorial reach will automatically "internalize" more pollution problems to itself than would the single firm or municipality. The emphasis in a regional system should be to consider flow augmentation, collective waste treatment, stream specialization, arrangements to transport wastes to offsite disposal, and other possible options as part of an overall
system in which each element makes its appropriate contribution to the whole. Another solution is a system of financial incentives, relying primarily upon a graduated effluent charge or tax to polluters, so designed as to encourage waste reduction by the firm. Ideally both approaches might be combined for an optimum system of waste control.

The upstream waste discharger needs to view the downstream costs he creates as opportunity costs in his operation. It is through standards and charges that devices are present for redistributing opportunity costs. The effects may arise in treatment, process and product adjustments, or in industrial location decisions.

The objective should be to provide a means for achieving a marginal cost of further abatement that approximates the marginal benefit of further abatement. Kneese and other economists have urged that the best way to make marginal costs more nearly equal to marginal benefits is through effluent charges rather than through subsidies or regulation. In essence, they argue that effluent charges provide that economic incentive which automatically leads the firm to its least cost alternative for handling its wastes.

Kneese has cited the cooperative water resources associations in the Ruhr River Basin of Germany (the "Genossenschaften") as the best existing example of an institution which approximates the solutions he is recommending, though even the Ruhr experience probably does not furnish a complete parallel or full test of Kneese's proposals. The emphasis in the Ruhr is upon water quality management. A river basin is used as a regional focus for managing waste effluent that is discharged and borne by subsequent users, as part of a broader river management scheme. Externalities are limited to the river basin and therefore are
dealt with in the basin context. The Ruhr system uses a basic charge contingent upon the amount and quality of effluent discharged by the industries. The charges are intended in part as a means of compelling waste dischargers to compensate for spillover costs or externalities placed upon the general economy. The charges are designed to provide an incentive for dischargers to take all external costs into account when making decisions about the extent and method of discharging their effluents.

The regional systems approach attempts to use more sophisticated tools for seeking economic efficiency than would be used in dealing with individual plant problems. The regional approach appears to be most applicable in highly developed river basins, and Kneese questions whether it can be successfully implemented over large regions of relatively unconcentrated pollution discharges.

A Problem of Implementation: Deficiencies in Data

Many obstacles lie in the way of achieving least cost solutions to water pollution problems. Not the least of these is posed by difficulties in securing the necessary data for solutions, no matter which policy route is selected.

If all of the relevant plant data were available and all values were known, definite specifications could be prepared for each polluter, indicating the amount by which his wastes should be reduced and the manner in which this should be accomplished. In actual fact the necessary data and values are often deficient by a wide margin. At the plant level, the individual plant in many cases does not get separate
information on such aspects of production processes as water intake, recirculation, waste water contribution of individual plant sections, or even particulars of waste effluent. And from a system point of view, the value data needed for computing the social cost of pollution are also hard to accumulate. Waste water is a function primarily of quantity, quality, operating rate, production processes, product mix, and effluent controls. It is the nature of these factors and how they influence water utilization that is important to the water economics of the individual plant.

As to waste treatment, the plant should relate treatment capacity needed to pounds of BOD effluent contributed from each production process, in order to create greater economic incentive to reduce wastes. This would enable the plant to account for its waste costs by production process sections. In this way there would no longer result the diffusion within the plant of responsibilities for the total waste problem. All of this would connect waste loads with costs involved so that a better effort might be made toward achieving minimum costs for the plant.

As to in-plant processes, it is only to be expected that a plant manager will be disinclined to change operating procedures that are working satisfactorily. And when process changes are under consideration, the evaluation context may often be limited to a single factor, such as the net production cost of the changeover, or the effect on waste loads alone. What is needed in order to achieve least cost solutions, however, is a simultaneous consideration of production costs of a changeover, potential waste load reductions, and waste treatment
facilities that would be needed in the absence of or to supplement process changes. It is at this point -- an overall evaluation of process changes and treatment needs for the plant -- that deficiencies in data so frequently stand in the way of effective analysis.

Turning to the system context, if all pollution damages were measurable in market value terms, a value model could be constructed for minimizing social costs of pollution. Marginal costs of waste disposal could be equated with marginal social costs, so that the least cost solution could be determined. No actual measure of all pollution damages is available now, or potentially available in the foreseeable future, however. At best, some surrogates or substitute methods of measurement may be utilized. One such avenue for estimating the social cost of water pollution might be to determine the cost of producing fresh water. In terms of reprocessing water where such may be the only alternative available, the cost of the processing could serve as the maximum value of water. The social cost of pollution would ordinarily lie somewhere below the cost of reprocessing the used water.

To summarize, there are significant deficiencies in the data needed for efficient industrial water quality management, both in terms of cost data for the individual industrial plant decisions and value data for overall system decisions. In many industrial installations, even the exceptional plant manager who is in complete sympathy with water pollution abatement objectives may find it difficult to amass the data required for a simultaneous evaluation of all relevant factors. The system policy maker confronts similar problems of data deficiencies. If he seeks assistance from industrial managers in bridging the gap, he is likely to
be told that the information cannot be supplied because it is proprietary in nature and might be used by competitors to the plant's disadvantage.

One of the arguments in favor of greater reliance upon effluent charges in place of regulatory controls goes to this data gap. If the schedule of effluent charges were set sufficiently high to be a significant economic factor for most plants -- something that would doubtless require some experimentation -- plant managers would soon realize that economic survival depended upon obtaining the data needed for least cost solutions. With the prod of economic necessity, the feasibility of arrangements to secure and maintain the requisite data would undoubt-
edly soon be closely examined.
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CHAPTER 4

A GENERAL REVIEW OF PRODUCTION PROCESSES, WASTES, TREATMENT, AND ECONOMIC IMPLICATIONS OF WATER UTILIZATION IN THE TEXTILE INDUSTRY

Not only has the textile industry developed a rather complex industrial organization and structure, but the in-plant workings are likewise quite complex and varied. There exists a countless variety of yarns, blends, fabrics, colors, and formulas from which the natural and man-made fibers are processed into the variety of finished products purchased by the ultimate consumer.

This chapter, which consists largely of a summary of recent textiles literature, begins with a general description of textile production processes. It then describes the wastes resulting from wet-processes, which are the principal sources of water pollution from textile mills. Next, it considers possible in-plant changes in the wet process phases that might reduce waste loads, and it reviews the economic implications of such in-plant changes. Finally, it describes methods of treatment that have been used for textile wastes, and touches upon the implications for public water pollution control agencies of the alternatives of waste treatment and in-plant process changes.

Because of the complex structure of the textile industry and the variety of textile products produced, production processes and water use patterns in this industry often vary greatly from one individual plant to another. This element of uniqueness makes it difficult to generalize about production processes and water use in the textile industry. Some general description of these matters is needed, however, as background for the case studies in Chapter 5.
Production Processes

The production aspects of weaving and dry-finishing do not ordinarily involve water problems. This discussion thus focuses on the wet-processes of in-plant production. These processes are desizing, scouring, bleaching, mercerizing, dyeing or printing, and finishing. It is the liquid wastes resulting from these processes that create the water pollution problem in the textile industry. These processes take place primarily within the dye and finishing plants of the industry. The highly variable character of these wastes adds significantly to the uniqueness attributable to each plant within the industry. In addition, the amount of water consumption by each processing operation varies greatly, along with fluctuations within the same process. Such variation depends upon the type machine used, the shade of dye desired, and the type and weight of fabric manufactured.

Even before the water enters the in-plant production process certain preparations may be required. Some of the prime considerations are reasonable degree of freedom from water hardness, removal of turbidity, removal of iron and manganese, and removal of coloration. These preparations are usually needed in order that proper dye results can be obtained.

Although the discussion of wet-processes centers around the dye and finishing plant, a textile mill may be involved in any one of the following operations: spinning, narrow fabric weaving, broad fabric weaving, spinning and broad fabric weaving, spinning-weaving-finishing, and finishing. A listing of the nine groups of woven goods into which the industry's products are classified by the Bureau of Census lends further insight into the variety of production processes that must go into the production of these goods. The groupings are: cotton duck and allied fabrics; narrow sheeting and allied
coarse and medium yarn fabrics; print cloth yarn fabrics; napped fabrics; colored yarn fabrics; fine cotton goods; towels, toweling and dish cloths; wide cotton fabrics; other woven fabrics and specialties.

Cotton Production Processes. -- Cotton may be used as a good representation of textile production processes. Man-made fibers follow a pattern similar to that of cotton.

The cotton bales are opened, cleaned, rolled in sheets, carded, and then spun into yarn. In order to strengthen the yarn for weaving, the yarn goes through the slashing process (sizing), which stiffens the fiber with starch mixture or some other sizing application. The washing out of the starch kettles, machines, and leftover size results in a small amount of liquid waste. This waste is strong in pollution contribution but low in volume. Starch sizing is used in most mills, although two substitutes are polyvinyl alcohol and carboxymethyl cellulose (CMC). The latter two contribute a lower BOD load but are more expensive per unit than starch.

The sized yarn is subsequently woven into fabric, called greige or grey goods. The grey goods then either go to the dye and finishing operations within the plant or else are sent to dye and finishing operations at other locations. In order to prepare for the dyeing and finishing of the fabric the size must be removed from the material. This removal may be done by a hydrolysis of the starch size, by acid or by enzymatic means. Some plants eliminate the desizing operation by a boilout operation known as kiering, which yields a considerable alkali waste.

Following the kiering or desizing operation, bleaching processes remove the natural coloring matter of the fiber by such applications as chlorine, hypochlorite, or peroxide. But it is previous to this bleaching
step that the kiering or desizing had already contributed the single most concentrated percentage of pollution within the textile process overall.

Following bleaching the fabric can be mercerized via a caustic solution. Tension is applied to the cloth during this process. Since the mercerizing caustic may be recovered for reuse, the wash waters from this operation are not highly polluted. However, mercerizing is not done in many plants — or, many plants do not mercerize on a large enough scale for recovery to be economical.

The dye processes are complex and varied. This operation brings the largest volume of waste waters; these waste waters vary according to the dye used. Even though the waste water volume is large from this process, the pollution content in the dyes is minor. However, the dyes do present a considerable coloration problem in the effluent.

Figure 1 below gives a general diagram of the operations from raw cotton through the finishing operation. Those production processes with asterisks indicate wet-processes.

Figure 1.
Except for alternatives available wherein dyeing or finishing might take place earlier in the flow chart, plus the exception where some slashing (sizing) wastes will occur, the remainder of the wastes occur in the dye and finishing plant.

**Wet-Process Wastes**

**The Textile Industry Generally.** As already indicated, the wastes resulting from processing fibers vary considerably and cannot all be handled in the same manner. Wastes may be from separate processes or they may be combined from desizing, bleaching, dyeing, mercerizing, or finishing wastes. These wastes curtail the growth of aquatic organisms. Such difficulty arises due to high pH factor, temperature fluctuations, different flow patterns of the wastes, oxygen content of the receiving streams, and BOD (biochemical oxygen demand) of the wastes.

The textile industry contributes three basic types of pollution: biochemical oxygen demand, inorganic waste, and color. The organic wastes create BOD, the inorganic wastes affect the pH of streams and produce toxic reactions in biologic life, while color is largely an esthetic pollution problem.

**Wastes from Wool and Synthetics.** Natural impurities contribute most of the pollution in wool scouring wastes, while process chemicals contribute most of the pollution in synthetic fiber wastes. Since synthetics have no natural impurities, their BOD is created in the scouring and finishing processes. The BOD loads are lower than those of natural fibers, while wool scouring wastes are higher. In the synthetics, polyesters produce wastes with the greatest pollution potential, the principal sources coming from the dyeing-assistants used.
Cotton Wastes. -- Cotton process wastes with their organic nature place a demand upon stream oxygen content. If the stream is not capable of oxidizing this organic material, putrefaction takes place. The average citizen sees pollution from an esthetic point of view in terms of color, turbidity, odor, and solids, while the recreationist is concerned with fish life in streams and boating or swimming availability. All of these concerns are a result of wastes entering receiving streams.

The origin of the BOD of cotton wastes comes primarily from two sources: natural impurities (approximately 25-33%) extracted during scouring, and chemicals (approximately 67-75%) used in slashing and processing. Glucose is the biggest BOD waste producer, which is discharged during desizing via hydrolysis. Regardless of the process used, the combination of desize waste and caustic scour waste will produce at least 67% of total plant BOD, and averages from 75-85% most of the time. Besides the BOD discharged, considerable alkalinity is also discharged (especially from scouring and mercerizing processes).

Although different researchers give varying figures as to pollution contributions of different production processes, below is given a representative breakdown of the percentage contributions to pollution in a cotton textile plant:

- desizing ................ 45% of total BOD
- scouring ................ 31% of total BOD
- bleaching ............... 3% of total BOD
- mercerizing ............. 4% of total BOD
- dyeing and printing ...... 17% of total BOD

It is difficult to become more specific about the textile wastes in the sense of listing actual chemicals and impurity amounts with their resulting
BOD or other effects on streams. There are various publications that attempt to give such details. But once again the difficulty is in moving from generalizations to specifics, as the inputs, etc., of each plant vary in kinds and amounts. In addition, the given BOD effects discussed in the literature will likely not be the same as those for the actual plant, while each plant may obtain a different result in its compilation from that of other plants. At least a relatively representative comparison of chemical or other BOD effects could be obtained.

**Wet-Process Changes Affecting Waste Loads**

Waste is best controlled at its source. Therefore all means of reducing pollution within the plant and at the points of origin within the plant should be attempted. In-plant changes in manufacturing processes may involve substitution of materials, reducing the amount of reagent used, etc. This section reviews some of the productive possibilities for in-plant changes in textile mills.

**Desizing Operations.** Naturally, since the desizing operation represents the single most significant source of pollution wastes in the textile industry, it would be just as significant for the handling of wastes if some change could be developed that would cut the BOD load contributed by this process. It has been stated that as much as 60 per cent of the total BOD of streams receiving finishing plant wastes could be attributed to warp size. It would appear that two alternatives are available in dealing with this problem. First, to recover the warp size from the desizing solution and either dispose of it as a solid material or try to reuse it as a warp size material again; or second, to find some other input other than starch to use in sizing, which has a lower BOD contribution.
Ideally, the effluent starches resulting from desizing operations should be oxidized by the bacteria present in the receiving streams. The starches that usually go into sizing compounds commonly are easily consumed by bacteria in the stream. Modified starches and the semi-synthetic, CMC can be consumed by the bacteria in the stream only after an adaptation period of five days or more. Therefore such wastes fall outside of the common standard 5-day BOD measure. These wastes (such as the CMC) can either result in little pollution if the wastes are sufficiently diluted before they create their activated oxygen demand on the stream, or they can result in pollution damage if their oxygen demand operates in stream areas of inadequate stream flow or quality.

The fully synthetic substance such as polyvinyl alcohol is not amenable to biological oxidation. Unless such a waste contains a toxic substance like chromium, no serious pollution problem should be expected.

Polyvinyl alcohol has been used to a limited extent in some plants, while CMC has been used to a somewhat greater extent in some firms. However, neither of these potential substitutes for starch, in terms of BOD contribution alone, have been generally incorporated into the desizing operations.

**Bleaching and Mercerizing Processes. —** BOD reduction possibilities in bleaching and mercerizing processes are negligible since these processes have a low pollution contribution potential, 3-4% of total plant BOD.

However, in the mercerizing operations of mills, a study can be conducted to determine if the amount of mercerizing is on a sufficient scale to warrant a caustic recovery operation. The caustic in used liquor, if its content is not too low, can be evaporated, purified and reused. The recovery and re-utilization of caustic reduces the caustic content and pH of bleachery wastes. Thus, the alkalinity present in waste is greatly reduced.
Dye Operations. -- The dye process contributes from 10-30% of total plant BOD. Soap, acetic acid, sodium acetate, sodium sulfide, sodium hydrosulfide, sodium sulfite, glucose, and emulsifying oils are major contributors to the dye wastes and should be replaced by suggested substitutes. Total plant BOD could be reduced from 5-25%, depending upon the amount of cloth dyed and the process chemicals used.

Not only must the wastes from dye operations be considered, but the color effects observed in the water are esthetically disturbing.

A study by Murdock suggested that sodium sulfide and metallic salts in the oxidizing bath gave the most trouble due to presence of chromium (a toxic chemical). The resulting waste effluent from these dyestuffs cause marked changes in color of the effluent stream. This particular study by Murdock solved the problem by taking the dye wastes and separating them from the other effluents for specific treatment.

In a study in North Carolina such dyes as sulphur, direct, vat, acid, developed, naphthol, and disperse dyes were observed. The main pollutional characteristics of their wastes were noted as intense color, high pH and alkalinity, high COD (chemical oxygen demand), high chlorine demand, high temperature, and extreme toxicity of sulphur dye wastes. Suggestions for treatment of these wastes were: equalization of the strong and weak wastes, neutralization of acid and alkaline wastes, proportioning the flow into sewage flow, removal of color, and removal of oxygen and chlorine demands via aeration, chemical precipitation and biological oxidation.

Acetic acid is a big BOD creator in dye operations since it is used by many mills as the acidifying agent in the dye house. It may comprise as much as 50-90% of the dye house waste BOD, which may amount to 15-30% of the total plant BOD. Mineral acids may be substituted in place of the acetic acid. For example, if hydrochloric acid replaced the acetic, the BOD would be eliminated.
since a mineral acid would have replaced an organic acid. Once again, on BOD pollution grounds alone, such a substitution is warranted. Other substitutes could be sulphuric acid or ammonium sulphate. The effects of odor from the sulphur replacements is reason not to encourage their use as substitutes.

In the printing process waste effluents are made up of high concentrations of natural and synthetic thickeners, softening agents, and adhesives, besides the dyestuffs. Fabrics are given special finishing qualities such as water repellency, fire resistance, and wrinkle resistance. Industrial fabrics and carpets require special coatings. The printing and dyeing processes contribute approximately 17% of the total mill BOD wastes, which is further incentive to reducing their BOD contribution.

Miscellaneous. -- A non-chemical process change involves counter-flow action in which the liquid proceeds in the opposite direction or flow from that of the production processed fabric. Thus, the fresh liquid first treats the material containing the least soluble or reactive matter. As the counter-flow continues, the liquid treats the material containing the more removable or reactive material. By doing this, the discharged effluent is lower in volume of water used and contains a higher concentration of impurities.

Recovery of waste heat often overlooked in textile plants, offers further possibilities for in-plant adjustments. The heat in waste effluent has a detrimental effect on the oxygen content of water. The heated effluent, if significant enough, will reduce the biological oxidation ability of the stream. Some of the suggested essentials to help plants better utilize their heat are the installation of proper instrumentation, control of humidity, and better organization of plant process cycles to take advantage of steam and peak load heat.
The ideal solution for the textile mill is embodied in changing production processes wherever possible, making chemical input changes to lower BOD choices, segregation of waste concentrations, equalization of flows, recovery, and finally, treatment plant installation. As much as 75% of textile wastes are relatively clean wash waters. Careful design towards separating these from the other 25% of high concentrated wastes of course would be desirable. The real problem of separation appears when goods are processed and washed in the same machine.

In order to bring about wet-process changes, regardless of what they may be, the changes implemented should not affect the quality of product in a detrimental way, new pollution problems should not replace old ones, and BOD of total plant effluent should be reduced. Economic justification of changes is a very important consideration in plant policy. Some economic implications of what has been discussed are now considered.

Economic Implications of Wet-Processes and Wastes

Changes in production processes to alleviate pollution problems must be evaluated in terms of their effect on a plant's economic efficiency. At some point social policy constrains the profit-maximizing efficiency objectives of the plant.

Size wastes. -- The dye and finishing plant is the center of consideration in water problems because it must eliminate the size in the materials received from the grey mills or produced by its own plant. The grey mills have only size-box wastes, while many of the yarn mills only make yarn and sell it to other plants for further production.

Substitution of CMC for starch in a plant's sizing operation could substantially reduce the five-day BOD contribution of size wastes. However,
most plants have been reluctant to make this substitution due to the greater expense of CMC, relative ease of using starch, the good qualities of starch, and reluctance to disrupt conventional procedures. In addition, because most cotton mills are commission houses (receive grey goods from other mills for finishing), they have no control over the amount of slashing (sizing) starch that plants apply to grey goods; nor do they have control over the decisions of other grey mills using CMC. Those finishing plants that could change over to CMC for their own grey goods lack incentive to do so unless they happen to deal only with goods they had control over in sizing operations.

Some data obtained during the period of this study (1966 and 1967) supply the following comparisons: a plant sends 200,000 yards per day of cloth through the plant, weighing 4 yd./lb., for 250 days/year, with 12 per cent starch on half the cloth and 5 per cent CMC on half the cloth. The cost of starch was put at 7¢/lb. and the cost of CMC at 35¢/lb. The annual cost of starch on this basis comes to $52,500, while the annual cost of CMC comes to $109,375.

It should be noted that these are only material costs, with unit prices only approximate. According to these figures, the CMC cost is approximately double that of the starch. (Other figures that have been cited could significantly affect the answers. For example, the following ranges of price and material requirements also encountered in this study would produce results favorable to CMC: 18¢ lb. for starch versus 35-40¢ lb. for CMC; 15-18% starch requirements owf, i.e., "on weight of fiber," for starch and 5-7% owf for CMC.)

Starch exerts a much heavier immediate BOD than CMC. In terms of 5-day BOD, starch requires 550 parts of oxygen for breakdown in 5 days, while CMC
requires only 17 parts of oxygen.* If one could isolate the reduced treatment costs due to the use of CMC as against the starch, then this saving could be applied to the CMC cost figures. The subsequent adjustment would indicate, in economic terms only, the advantage of one chemical against the other.

Another possible sizing agent is polyvinyl alcohol. At one time streaking in the dye finish was noted with polyvinyl alcohol, even though it was a better sizing application than CMC. (This is so because polyvinyl alcohol reduces the percent solids in the size from 7% as in CMC to about 3.5% in polyvinyl alcohol.) Some later experience, however, indicates that it may be possible to eliminate streaking. Polyvinyl cost quotations at the time of this study were around 45¢/lb., as against CMC at around 35¢/lb. Under such a cost comparison, the polyvinyl alcohol appears to be more economical, because its application on materials is half that required when using CMC.

Dye operations. -- In the case of substituting diammonium phosphate for acetic acid in dye operations, assume that the change is made on the basis of chemical equivalency, for purposes of comparability. The cost cited to the author were approximated as follows: acetic acid at $0.166/lb., and diammonium phosphate at $0.112/lb. One pound of acid is the equivalent of 2.2 lbs. of diammonium phosphate. By substituting for acetic acid, the cost of the substituted chemical equivalent will have increased 48%. Again,

* However, there may be offsetting disadvantages for CMC. While it has a reduced effect on 5-day BOD, it has a potentially large 30-day BOD, which might be activated at a great distance from the point of origin, unless it reached the ocean prior to activation of this potential. Also, CMC is alkaline high and this causes problems such as eating at metal in loom harnesses.

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the economic incentive for making such a change has to come from a source outside the chemicals themselves. As in the case of CMC, it would seem that the BOD load would hold the key to that incentive, or else some other BOD constraint or outside restraint would have to require substitution to be made.

**Recovery of materials.** In the case of caustic recovery, plants have installed such systems only if they have obtained processing cost savings. The scale of operations determines the economic advantage to such an installation.

In the case of dyes, many dyes could be recovered, but because of the small amounts present in solution, expense of recovery far exceeds the cost of the pure dyestuff. Indigo once was recovered in large amounts until the introduction of more efficient indigo dye methods eliminated much of the indigo in effluents.

**Water utilization.** There is little doubt that in many dye and finishing plants, water is wasted on a large scale due to poor housekeeping and inefficient use of water and equipment. The costs of water utilization as an element of total plant costs or sales largely determines the economics of alleviating rather than tolerating the water pollution problem.

In connection with plant rinsing operations, the rinse water requirements per unit of finished goods depend upon the number of rinsing operations and the amount of water used in each rinse. Subsequently, the water requirements depend upon the type of chemicals and dye which have been used and upon the type of dye equipment.

The method of rinsing also affects the water use; as in yarn dye machines, the individual rinsers require less water than continuous rinsing.
Although water seems to be present in sufficient quantities, its importance as a raw material in the cost of manufacturing processes is often underrated.

Water reuse to cut water volume needs is gaining increasing attention from industry. With water reuse, the resulting pollution concentration of the effluent is greater per gallon, while hydraulic volume is less. This in turn makes the pollutant correspondingly more economical to remove by treatment.

Treatment of Processing Wastes

The traditional answer to industrial water pollution problems, assuming public treatment facilities are not available, is construction of individual plant waste treatment facilities. The principal considerations relating to treatment are the size and quality of the receiving stream flow, and the volume and pollution strength of the waste. Extent of treatment also depends upon the use-classification of the stream. If combined treatment of industrial and domestic waste can be implemented, doing so may reduce overall costs of capital outlay, provide more economical operation, dilute textile waste, and reduce municipal treatment plant size required (if effluent enters municipal system).

Separation of wastes can be accomplished by mechanical filtration and screening. In addition, wastes may be handled by equalization of flow, separation of concentration types, and lagooning. Where feasible, it may be advantageous to separate wastes for mercerizing, desizing, and dyeing, so that the plant can treat each of these wastes at their point of consequence, rather than lumping all the wastes together and then treating.
Separation of wastes may prove quite expensive unless the necessary drains and piping have been included in the design of the original mill. This emphasizes that only the new plant is likely to take advantage of economies of engineering design. Efficient engineering can lead to optimum water usage. Allowance can be made for flow equalization and separation of concentrated wastes from more dilute wastes. Waste flow measurements should be taken so that a rational disposal program is feasible. It is important to know the pathway of each of the waste pipe flows and with what wastes each pipe blends. Here, serious obstacles may be encountered in old mills whose pipes are difficult and expensive to locate.

Chemical treatment includes alternatives of neutralization, coagulation, precipitation, and oxidation. Biological treatment most commonly utilizes trickling filter, contact aeration, activated sludge, and sterilization ponds.

Treatment via trickling filter or activated sludge is best used in cotton mill waste treatment. If chemical coagulation is used, as for synthetics, the waste discharge should be equalized in order to handle wastes properly.

Lagoons and water towers may be used to cool a hot effluent. If a plant were located with a large land area available, lagooning would be useful because it is a very low cost treatment that can reduce BOD as much as 50% when used prior to filtering or aeration units.

Most mills use some form of activated sludge and extended aeration. The individual treatment depends upon the character of the individual wastes, costs of in-plant changes, benefits of segregation of weak effluent
with little or no treatment, and design requirements. Aeration inhibits anaerobic decomposition, while neutralization (pH adjustment or alkalinity as to acidity) is usually a prelude to some other phase of treatment alternative.

It is necessary to define waste loads and how waste loads vary for the product mix involved for any given plant output. Always present is the problem of uniqueness to each plant and therefore the difficulty of attempting to generalize.

One might ask how does the treatment plant adapt to change, if the industrial plant depends upon the treatment plant to control the waste load? The plant might attempt to get a neutralization process so that further expanding of the existing treatment plant is not required. Or where detention time of 24-48 hours aeration may have previously been required, expansion of production may require cutting aeration time to 12-24 hours while maintaining the same BOD level of effluent that had previously existed. In such a case, treatment would have been doubled without expanding the treatment facility. Many mills plan their treatment plant installations so that the build-up of increased production and/or additional BOD can be accommodated adequately.

**Treatment costs.** -- Some concept of the general magnitude of waste treatment costs can be gained from the following estimated data supplied at the time of this study for a plant in North Carolina:

- Flow: 10 mgd of production process water
  - 76,000 gpd of domestic waste waters
- For: 50% reduction of BOD ---- $ 580,000
  - 75% reduction of BOD ---- $ 900,000
  - 85% reduction of BOD ---- $ 1,175,000

Such figures, due to generalizing, do not include the type of plant involved, the alternative treatment plant possibilities, detention times possible, types
of wastes involved, or any reference to potential or already realized changes in process design or handling of wastes. The figures do give some indication of the significance of the cost of treatment at varying degrees of treatment efficiency.

Another example of capital cost that was supplied to the author involves the alternative of pumping 3.0 mgd a distance of 2.3 miles to a treatment plant, as against no cost of pumping for gravity flow to the nearest receiving stream. The pumping cost in this instance would have been $244,000.

Another example involves the cost of concrete versus earthen retention basins for treatment. Assuming a flow of 10 mgd is involved, a retention time of 2 days, and ideal conditions for construction, the following figures were supplied:

<table>
<thead>
<tr>
<th>Material</th>
<th>Cost per Cubic Yard</th>
<th>Total Cost</th>
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</thead>
<tbody>
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A choice may depend further on the relative hauling costs. Other considerations entering in would involve topography, available area, location, accessibility, and other concerns. A clarifier for the above example would run to approximately $180,000.

Whether the ultimate waste in the plant effluent has been reduced through production process alternatives or through final treatment system, the nature and quantity of wastes and the economic evaluation of alternatives must determine a solution for each plant. This solution in turn
depends upon the constraints placed on the plant by plant location (especially, relative to size and quality of receiving stream) and by public policy. As has been previously indicated, the choices that are made often may reflect to a considerable degree the availability or unavailability of relevant data.

Implications for Public Agencies

One clear implication for public agencies having water policy responsibilities is that their view of the pollution problem and their authority to deal with it should be broad enough to take into account all significant alternatives -- including industrial treatment plants, public treatment facilities, and approaches that do not involve treatment (or involve treatment only supplementally). For example, as we have seen, there is evidence to support the proposition that individual industrial waste treatment plants should be viewed not as the preferred or the normal solution, but, at best, as one of several competing alternatives. It is felt by many that too much attention is being given to this particular abatement alternative, rather than to making every effort to reduce pollution prior to the end of the plant production process. If the responsible public agencies lack either the authority or the will to consider other alternatives, it is quite possible that their programs are failing to achieve their objectives by a wide margin.
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In the course of this study approximately a dozen wet-processing textile plants were visited in North Carolina. Numerous interviews were also conducted with persons connected with the textile industry in North Carolina. This chapter summarizes the results of the plant visits and interviews, and sets forth some general conclusions from the case studies.

Resume of Plant Visits

Plant A

This mill disposed of its wastes directly into a receiving stream until a treatment plant was installed recently. This treatment plant was installed as a result of the SSSC (North Carolina State Stream Sanitation Commission) standards, designating this stream a class "D" stream. The investment in the treatment plant brings no direct benefit internally to the plant. In this sense it is viewed as an out-of-pocket cost.

The water flow of the plant has the following general pattern: water is impounded in a pond from a running creek. This water is then pumped uphill where it is settled and pretreated in order to obtain desired purity and softness, so that it can then be sent by gravity flow to the dye operation. The water then enters vats for dyeing, is used to wash vats, and then is run directly into the treatment plant. There is no recycling of water, nor any felt need to economize on the use of the water supply. If intake water is low during the summer, the plant resorts to pumping water directly out of the receiving stream at a point above the treatment plant.
Plant management noted that the water intake from the receiving stream is generally cleaner than in earlier years. Perhaps this is due to the increased upstream municipal and industrial waste treatment installed in recent years. This implies some indication of the external nature of economic benefits and costs—the downstream plant hopefully benefiting from upstream treatment in one instance, while the upstream plant must incur costs of treatment in order for downstream benefit to occur but whose benefit is external to the upstream plant.

The present treatment plant for wastes was chosen after many possibilities were investigated in an attempt to use the most economical treatment in terms of the needs of the plant. Because of existing plant location and lack of sufficient area, lagooning could not be utilized. To locate a lagoon at some distance from the other plant operations would have incurred excessive pumping costs.

Of the approximately 725,000 gallons per day used, approximately 400,000 gallons goes to the treatment plant, while 325,000 gallons are separated in the system to go directly into the receiving stream without full treatment. All of the effluent is screened for solids, which in turn are periodically pulled-out and buried.

Other uses of the water in production processes besides that for dye operations, go for boiler needs, steam for drying needs, humidifying needs in the plant environment, needs of water in materials, plant domestic sewage, plant housekeeping, and mercerizing operations.

Plant B

Plant management considered its operation one of desired economy of scale and efficiency. The total operation involved grey goods and
finishing. Cotton and synthetics such as dacron and polyester synthetic yarns were used. A good deal of blending of natural and synthetics make up production, with approximately 300 different styles involved.

The complexity of production in this plant is mentioned to illuminate the unique production mix of a single plant. Yet every plant mentioned, whether more complex or less complex in its operation, had some unique characteristics.

This plant relied primarily on its treatment plant for solving its waste problem. Again, the SSSC standards were the constraint which brought solution of the waste problem through installation of a treatment plant. The plant's 24-hour extended aeration treatment was designed so that volume could be doubled if necessary by cutting the detention time and increasing the aeration capacity pumped into the waste treatment. Such a change could be implemented for less cost than the alternative of increasing the hydraulic load handled by the treatment plant.

The plant could not utilize an earthen aeration system because of the existing location on a potential floodplain of the receiving stream. Therefore, the constraint of the receiving stream meant a greater cost to the plant then if a more ideal plant location had been feasible.

Plant C

At this vertically integrated cotton mill an interesting point was made in regard to their placement of energies toward the changing of processes for increased efficiency and profits. Even though figures were not accurately available as to water investment and processes, the importance of water was not questioned. That is, plant operation of wet-processes and total plant operation depended on the proper supply
of water. At the same time, the amount of water used was not regarded as an important cost factor for the plant. The piping, pumps, and treatment facilities existed, but exercised no further claim for management attention.

The attitude of management at this mill probably typifies that of many plant managers. Management at this mill emphasized that the small mill is in business to make a profit and it cannot afford research programs in all areas of operations. Therefore it spends its efforts in directions that will be the most economical for the time spent.

In this instance, the greatest research effort and change in production process were aimed at experimenting with dye blends, to find the most inexpensive means to accomplish the desired ends of color blend and quality on the product.

Without stating specific water costs as part of the total costs of the mill, it was indicated that mill water costs are a small portion of total costs. To spend time and energy investigating water process changes was felt to bring relatively small savings. On the other hand, a saving in dye supply costs could bring a much greater saving.

An example was given regarding the economies obtainable in dye selections. The dye used on a particular fabric was changed from one kind to another kind of application. Both dyes were capable of achieving the same shade and quality of result on the fabric. Based on the production of the fabric involved and the pounds of dye involved, the plant had saved approximately $35,000 in a given period of time.

The plant did use a heat exchanger system in connection with its dye operation and yarn kiering system.
Plant D

Plant D has no desizing operations. This reduces considerably the extent of the plant waste problem. The plant uses spun cotton and almost every fiber made.

When the constraint of SSSC standards became inevitable, the plant attempted to avert the necessity of having to build any treatment plant at all. The attempt centered around taking all the chemicals that resulted in high BOD creation in the waste water and then seeing if these chemical inputs could be replaced with lower BOD causing inputs. Some changes were made, but not enough reduction in BOD resulted. A treatment plant had to be installed anyway.

The changes made did cut the size of the treatment plant required and improved water utilization efficiency. The waste load was reduced. If high BOD is reduced but volume is not, the size of the treatment plant cannot be reduced. However, the size of the compressors, stirrers, etc., can be reduced and savings can be realized in electricity costs.

Prior to installing a waste treatment plant, the mill had a large amount of lint solids going into the receiving stream. Because these solids could cause some scum creation on the stream banks which could lead to stream odors, sieves were used to catch this lint on its way to the receiving stream.

In connection with the attempt to eliminate the need of a treatment plant, acetic acid was replaced by phosphoric acid, which reduced the BOD in the waste discharge and at the same time resulted in using a less expensive chemical (because it required less effort and less application per pound of material).
If the plant could separate diluted wastes from concentrated wastes, it would do so. This would not be practical to change presently due to the type of hodgepodge plant additions built through the passing years. However, with present day knowledge and concern for water pollution problems, they would implement such in the design of any new plant.

If the plant operation could be rebuilt today, management at this mill would probably:

1. separate dyestuff concentrations from rinse water, by sending rinse water directly into the receiving stream; this would reduce treated water volume approximately 20 per cent.

2. rinse more efficiently (use less water in their rinse operations).

3. in wet-finishing-scouring of piece goods, they use biodegradable detergents; utilizing counterflow measures and the biodegradables increases BOD about 10 per cent; this use would continue for business and economic reasons.

At one time this plant was using a chemical application which later became outlawed due to its effects on receiving streams. Due to such a physical constraint, the plant subsequently found that the same chemical could be applied in a different part of its production process in such a manner that all of the application remained in the material. In this case no economic loss resulted.

A great deal of the credit for the plant changes that have been described were given impetus due to the stream classification standards for
receiving streams. At the same time the mill operator when looking at process change possibilities, will be hesitant about implementing changes unless it is clearly going to bring him an economic benefit. Because most plants have been in existence for many years, their investments are already paid for. On the other hand, the new plant has the advantage of experience with water problems; new plants can be designed to take advantage of changes and innovations that otherwise would not be economical.

This particular plant has no heat exchange system or recirculation, as their effluent heat temperature is too low to be economically worth recovery. However, if the plant could separate its piping flows, then heat exchange would be worthwhile. Sunk-piping-costs in existing plants is probably the major reason many plants do not make changes affecting their water utilization and wastes.

**Plant E**

In terms of volume of water used at this mill, water per pound of goods processed has probably decreased while the number of pounds produced has increased. The ratio would probably be a little less than proportional. This is in spite of differences in water application for different weights of material.

A recent production process change hasinnovated the squeezing out of water from the fabric rather than just drying it. Now this plant squeezes out approximately 70 per cent of the water in the cloth. At the same time, the more water squeezed out in one step, the less needed to squeeze out in subsequent baths (the polyesters absorb less water and are easier to dye).

Management at this mill compared CMC unfavorably with starch as a sizing agent. The latent BOD of CMC was stressed, as well as its low rate of utilization in the industry. It was also stated that starch can be applied to a larger portion of a mill's production than CMC.
Plant F

This is a mill which has thoroughly considered its water use in relation to its total plant design.

The plant uses from 2.0 - 2.1 mgd (million gallons per day) of intake water, while the inflow is fully treated including high rate sand filtration (alum, soda ash, and chlorine added to get the water to potable standards).

The plant operation has two systems of water. One involves sanitary use which is drawn from protected storage. From 0.4 - 0.6 mgd of this system is used for drinking water, kitchen needs, etc. The other system of use is for production process water, which is taken from open reservoir storage and includes from 1.4 - 1.6 mgd of water.

The primary uses of the process water go for mercerizing needs (0.4 mgd), dye uses in liquor baths and materials washing (0.7 - 0.9 mgd), and for bleaching uses amounting to 0.2 mgd (chlorine peroxide). There is no recovery of water due to the cost of breaking-out sulphur-chromate dyes, which are used in a large part of the production.

Of the 1.4 - 1.6 mgd of process water, from 0.8 - 1.0 mgd is hot water and 0.4 - 0.5 mgd is cold water. There are three areas of process water costs: (1) cost at point of use in the production process proper; (2) production cost (heating, piping, equipment to do heating); and (3) cost from use points to disposal in the receiving stream.

The cost of heating water is approximately 6-7 per cent of the total water costs from intake to outflow. This figure would be five times greater without the system of heat exchange which the plant utilizes to economical advantage. Dye liquor released at a high temperature is subsequently sent through a heat exchanger bank. The heat from this hot
liquor-release in turn boosts freshly heated water to a temperature sufficient for dye and bleaching operations. This is one case wherein the heat exchange system saves heating costs. The exchange system at this plant was amortized in 2.5 years through savings in equipment, fuel, and replacing what otherwise would have been needed in horsepower steam capacity without the heat exchange system.

A second heat reclamation occurs in the yarn dye operation when hot air at high temperature is run through chiller coils that causes moisture to be created at a lower temperature; this air is then reheated again to the high air temperature in a repetition of the cycle. The chill water created is non-contaminated and is discharged to the hot water system. Approximately 0.2 mgd is used in this heat reclamation and re-use of water through moisturizing the hot air. Actually a "triple" use of heat takes place -- twice in heating water and once in actual dye application. Without this recirculation an additional 0.2 mgd would be needed.

The plant caustic recovery system allows for an additional saving on heat, as condensate resulting from evaporations is fed back into the hot water system of the plant for additional use in the dye operation, where it too goes through the heat reclaiming operation. This represents a double use of water and of heat. The result is a saving of from 0.1 - 0.2 mgd.

The overall saving to the plant involves from 0.3 - 0.4 mgd. Once the dye contaminates the water, no reclamation of water takes place, as the water becomes part of the plant waste effluent.

Approximately 1.4 - 1.6 mgd goes into water waste disposal, of which approximately 0.2 mgd is lost through boiler-feed water loss, floor
washing, dryer loss, humidifying system, and in decreasing moisture in processed material.

The plant has an extended aeration lagoon with a 7-day retention period and equalized flow. It is a 2-stage lagoon with water finally discharged at 70-80 degrees. This may be compared to temperatures as high as 280 degrees reached in dye operations. If there is a hydraulic increase in water use, as anticipated, then the retention time in the lagoon would be reduced while the BOD load would increase about 20 per cent, under existing facilities.

If the plant were to take care of the increased production-caused BOD by use of a cooling tower, the hot plant water temperature could be reduced while simultaneously increasing the oxygen capacity of that cooling tower water flow. This would result in an increased coefficient of transfer to oxygen content.

Because of the presence of a relatively good receiving stream available for the waste effluent disposal, dilution of wastes is good. This helps to lower the amount of treatment that might otherwise be required. In contrast, a plant that must dispose of its wastes into a slow moving stream has a compounded problem because such a stream does not provide the benefit of natural flow aeration qualities. As a result such a plant must provide greater investment in treatment facilities. Additional esthetic nuisance of odors and color can also be a problem in such a situation.

Dye and finishing plants may do well to stay away from public highways and public viewing due to the esthetics problem and lagooning smells. One such plant had public feedback for such reasons; there probably have been other similar situations in the State. As a result, the constraint
of public opinion requires the plant to treat more than otherwise might have been the case.

Plant F did not encounter such problems since it had plenty of land area available for its plant needs, besides doing its lagooning away from public notice. Perhaps the fact that this plant was established relatively recently, in the 1950's, helped to increase management awareness of the importance of its water needs.

Plant G *

This plant is in the planning stages. It is projected as the third plant to be built in North Carolina by a firm that makes synthetic polyester yarn, Fiber Industries, and would be located in northern Orange County, near Chapel Hill. A discussion of the proposed plant's water handling will give an indication of what complete handling of industrial wastes can accomplish along the lines of water re-use in production processes.

Part of the impact of such a proposed complete system of water utilization reflects the firm's attitude on pollution control towards being good neighbors and trying to come forward on its own initiative with waste treatment plans that clearly exceed applicable regulatory requirements. Although the firm's second plant is one of the most modern in the State, the proposed plant will go two steps farther in treatment in order to obtain water of virtually potable quality.

The firm also follows the policy of using more expensive chemicals within reason, if it will keep the BOD out of the production processes.

The consulting engineer for plant water-handling prepared a report of the proposed treatment design for presentation at the 16th Southern Water Resources and Pollution Control Conference held in 1967. An accounting of this report on the re-use of plant effluent in process water

* The next several pages of description -- concerning the ill-fated northern Orange County Fiber Industries plant site -- were written in 1967, long before the developments in 1968 and 1969 that eventually caused the withdrawal of the plant. These later developments are summarized beginning at page 79. Pages 75-79 are presented in the present tense, as originally written.
follows. Treatment is for both industrial domestic waste and for industrial wastes resulting from polyester fiber wastes.

The proposed plant will be located on a receiving stream whose average flow is 20-24 cfs and whose 7-day-10-year minimum flow of record is from 0.0 - 0.1 cfs. The new plant would discharge an effluent of approximately 0.5 cfs in order to meet this minimum and to comply with state standards.

The new plant will go beyond the secondary treatment already established at the firm's other two existing North Carolina plants. These existing plants treat both industrial and domestic waste; they equalize the flow and concentration of the industrial waste and seed it with the domestic waste; nitrogen (ammonia) is added while additional phosphate is not required; the mixed waste goes to the aeration basin after which the treated waste is clarified. The sludge is recycled and a portion of the effluent goes to a series of polishing ponds; sludge buildup in the aeration basin is systematically diverted to the digestor basin; after sufficient detention time in the digestor, the inert sludge goes to a drying basin. Clear supernatant out of the clarifier goes to a polishing pond, is detained appropriately and then released to the receiving stream.

The combined domestic and industrial waste that enters the treatment plant has a BOD of 1500-3000 ppm (parts per million) and a COD approximately 10 per cent greater; while pH ranges from 8-10. This waste has the color of titanium dioxide and is rather opaque. Following waste treatment, BOD is less than 25 ppm with a color less than 50 ppm, while pH range is 7-8.
The extended aeration activated sludge waste treatment process just described is estimated to cost approximately $50 investment in capital equipment for each pound of BOD treated daily. This figure relates to waste treatment plants treating from 5,000 to 10,000 pounds of BOD per day, involving a hydraulic load of from 350,000 – 1,000,000 gallons per day.

The additional steps involved for the proposed re-use system at the new plant necessitates algae removal, carbon treatment, and chlorination. Also preliminary roughing with a plastic media trickling filter will be used. As a result of this proposed high degree of treatment and resulting quality renewal of water, water can be re-used in a number of major production process areas in the plant.

Besides the need to meet the 7-day-10-year minimum flow of record, the high degree of treatment at this site was further influenced by the proposed establishment of a multi-purpose federal reservoir, New Hope Dam, whose backwaters will tail-out approximately one mile below the new plant site. This reservoir is expected to be used for recreation and water supplies. Because of the anticipated reservoir location and uses, State Stream Sanitation officials were initially skeptical that Fiber would propose waste treatment adequate to protect the proposed reservoir. That is, state officials expected Fiber to propose a tertiary treatment plant, which -- though going a step beyond the usual "complete" or secondary treatment process -- would not in this particular location provide sufficient water quality protection. To the surprise of State officials, however, Fiber's engineers on their own initiative came forward with specifications for a treatment process going an additional
step beyond even the unusual tertiary process, and the State was thus enabled to give its blessings to the plant location and treatment plans.

The addition of the plastic media trickling filter has been termed economical since it will allow for a reduction in aeration basin space requirements and in initial capital investment and subsequent operation expenses. Such a filter will reduce the BOD approximately 50 per cent.

The carbon treatment will further reduce the remaining BOD and COD (chemical oxygen demand). As a result of this treatment, BOD will be cut to around 25, COD to less than 150, taste will be removed, odor likewise, while a color of less than 10 is estimated to result. This treated water will be recycled for use as production process water in the plant operation.

This company's long standing responsiveness to water pollution abatement goals undoubtedly played an important part in encouraging its consulting engineers to develop such a far reaching plan of waste treatment. Another key factor in waste treatment plans for this plant is the overall cost of water supply at this location. The cost of potable water piped to the plant is projected at from 20-28¢/1000 gallons. The minimum cost of waste treatment without the steps toward water re-use is estimated to be 10¢/1000 gallons. The water re-use costs primarily of carbon treatment which is beyond the dictates of usual state requirements for the receiving stream are estimated at 10-15¢/1000 gallons.

Therefore, the plant is faced with the alternative of obtaining intake water from outside sources at 20-28¢/1000 gallons as against the alternative of treating its waste for re-use. This cost is estimated at 10-15¢/1000 gallons for that tertiary treatment. According to these
figures the decision to re-use process treated waste water is the most economical alternative.

The feasibility of water recycling and re-use for a comparable plant will be pretested by Fiber at its polyester plant located at Shelby, North Carolina. Fiber plans to invest $150,000 in this project, which will be assisted by a demonstration grant of $350,000 from the Federal Water Pollution Control Administration. The Greenwood, South Carolina consulting engineers firm of Davis and Floyd, which prepared the waste treatment plans for the proposed Orange County plant, is helping to engineer the Shelby water re-use project.

Later developments. -- Normally the securing of state approval for the northern Orange County treatment plans would have ended Fiber's water pollution control problems for this installation. For reasons peculiar to the locale, however, this was not to be the case.

The receiving stream for the effluent from Fiber's proposed plant is New Hope Creek; a short distance downstream is Duke University Forest. New Hope Creek as it flows through Duke Forest has been used for research activities by aquatic biologists and other scientists. About a year before Fiber's plans were publicized, conservationists in the area had mounted a strong and successful attack against the development of a mining complex area, in part because of potential injury to Duke Forest. With this history so fresh at hand, Fiber's plans soon came under close scrutiny and criticism from conservation spokesmen.

A series of hearings and meetings were held on the subject before the North Carolina Board of Water and Air Resources and the Orange County Board of Commissioners. From these proceedings indications were that New Hope Creek is a small stream with minimal dry weather flows; that the
Stream is now classified as "D" for agricultural and industrial use; that much of the time, as a result of low flows or existing pollution, the quality of the waters is in fact no better than a "D" stream; and that the effect of the Fiber Plant would probably be to regularize stream flows and during low flow periods to improve the quality of the creek. Nonetheless, vigorous objections were voiced to the Fiber installation, ranging from expressions of concern over the potential disturbance of the ecology of the stream to careless accusations that the plant would change a pure and pristine stream to an open sewer.

Several suggestions were made for the purpose of insulating New Hope Creek from the effects, deleterious or beneficial, of the Fiber plant. Among these suggestions were piping of the Fiber effluent around the area and directly to a Durham treatment plant; recategorization of the stream from "D" (agricultural and industrial use) to "B" (bathing); and creation of a new "research use" stream classification. A recategorization to Class "B" was rejected by the Board because of staff advice that stream flows were insufficient to support the requirements prescribed for this classification -- even without any additional man-made pollution. Creation of a new "research" classification was rejected because of inherent difficulties in the definition of this proposed new category, legitimate differences of opinion as to the workability of a research classification, and incidental legal doubts as to the Board's statutory authority to create this classification. The possibility of piping the effluent to Durham was probably not then in the Company's sights, in view of its elaborately-engineered treatment plans. In time, though, Fiber might come to regret that the piping alternative was not quietly pursued at that early date (in 1968), before later developments were to drastically curtail its options.
Although none of these suggestions was accepted, the Water and Air Board did promise to give special enforcement attention to the area and adopted a requirement that "tertiary treatment" be given to all wastes discharged into this reach of stream. This unusual treatment requirement -- which has been adopted only in isolated rare cases in North Carolina or, indeed, in the nation -- serves to spotlight the advanced nature of the water pollution control measures proposed by Fiber, which planned to carry its treatment processes one step beyond the tertiary level.

If the developments of 1968 came as something of a surprise to a company that had prided itself in its waste treatment facilities, an even ruder shock awaited Fiber in 1969. During the spring of '69 a crescendo of opposition grew to the Fiber location, centering on the fears of conservationists and of Duke and U.N.C. scientists that the plant's wastes would doom aquatic research activities in Duke Forest. As often occurs in such heated debates, many exaggerated assertions were made about the blot that Fiber was allegedly prepared to visit upon the landscape -- in obvious ignorance of the company's extraordinarily enlightened waste treatment policy.*

* Reflecting the heat that was generated by these debates, at the height of the Fiber furor, a child's letter appeared in the Chapel Hill Weekly of July 2, 1962, (Section 2, page 2) reading as follows:

"To the Editor,

The following letter has been sent to Carl Smith, Chairman of the Orange County Board of Commissioners.

Dear Mr. Smith:

I am a Cub Scout. My name is Brent Elder. I am 8 years old. I like Chapel Hill and I do not want it to be messed up by factories. It pollutes the air and water. I do not want a factory built in Chapel Hill, especially one like Fiber Industries because it's so dirty. Please think about it carefully because I know lots of people who do not want a factory near Chapel Hill.

Sincerely,

Brent Elder"
The focus of objections soon settled upon a county zoning change that would be required in order to accommodate the plant location. At hearings on the proposed rezoning, widespread business and rural support was balanced by the opposition, officially expressed for the first time, of both Duke University and the University of North Carolina at Chapel Hill. U.N.C. Provost J. C. Morrow rested his opposition on the grounds that the plant "is inappropriately close to the center of Chapel Hill for industrial use" and would prevent development of the area "in the direction of the site."

(Raleigh News & Observer, July 15, 1969, p. 3) By this time, sharply polarized political divisions were apparent. Political camps tended to divide along traditional liberal (opposed) and conservative (favorable) lines. But some politicians (especially those aware of the company's relatively high wage and enlightened waste treatment policies) found themselves torn between conservation and university allegiances, on the one hand, and their painful awareness of the cost of losing a relatively high wage paying, large employer, on the other hand. (1,500 - 2,000 jobs were planned initially.)

Following the hearing, approval of the rezoning was granted by the county planning board, and it appeared likely that the plant would be located as planned. In an unexpected move, however, Fiber Industries withdrew its rezoning request and cancelled plans for the plant location. The company's reasons were made plain in a statement to the board of county commissioners: "We feel it necessary to have near unanimous support of all major organizations in a community" (Raleigh News & Observer, August 5, 1969, p. 1).

In retrospect it seem obvious -- as began to appear in the 1968 Water/Air Board proceedings -- that the most substantial ground of opposition to the Fiber plant was not objections to its water pollution control plans but
objections to its location based upon land use philosophy.* It is unlikely that any degree of waste treatment would have allayed the anxieties of the conservationist - the research group. And, though piping of plant wastes around Duke Forest to Durham might have satisfied these critics, it would not have been responsive to U.N.C. concern over proximity of the plant to its campus and surrounding residential community. Fundamentally, the debate about the Fiber plant involved a disputed land use decision. The long delay in coming to grips with this issue was responsible for a regrettable beclouding of the water quality aspects of this case. As a result, what Fiber proudly planned as a model waste treatment plant was represented in the public eye as a noxious intrusion upon a pristine natural area. And, among other things, this misadventure eliminated an opportunity to hold up this model plant as an example of desirable waste treatment practices to be emulated by industry generally and by the textile industry in particular. Some possible lessons to be drawn from this unhappy experience are considered in the Preface to this report (see pages vii - xi, above).

Plant H

This plant at one time made a production process change that involved the use of CMC as a substitute for starch in its sizing operation.

* There was also a rather sophisticated intermediate position: that (a) the company's waste treatment plans, no matter how highly developed, could not compensate for the inherent inability of the small receiving stream to assimilate the treated wastes of this large "wet" industry; and (b) therefore, either a change of location or piping the plant wastes to another location were the only adequate solutions.
When the plant changed to CMC, the BOD load was reduced from approximately 36,000 lbs./day to about 16,000 lbs. BOD/day. The changeover involved approximately 9,000 looms and about 3,500 different styles and patterns and weights of yarn and cloth.

The changeover to CMC was largely a result of the external suggestion of the state authority that the plant had better do something about the mounting pollution problem that was being created due to the BOD load of the plant.

The plant discovered that 80 per cent of its BOD loading was contained in approximately 0.6 mgd out of 15-18 mgd. The high BOD waste water was from first washings after dyeing, desizing, and mercerizing operations, with starch constituting the majority of the waste load.

In regard to plant dye operation, the attempt was to use up as much dye as possible with as little waste as possible, due to the high cost of the dye chemicals. As a result, dye wastes were not considered significant to the operation in terms of waste creation.

In terms of reduction of in-plant water use, meters or monitors checked the quantities of water needed for each of the washings, etc. For example, in the mercerizing operation this plant had been using 300 gallons/minute, and then found that 50-60 gallons/minute were just as adequate in obtaining the desired result.

Innovations of this nature do not come easily. For a mill to discard a satisfactory, production process the innovation must prove economical. Otherwise, it must be due to some external source pointing out the necessity of change on waste pollution grounds. Inertia, tradition, hesitancy to change, or absence of external forces seeking change, all may deter or retard change.
One further point was made about this plant and changes in waste handling. For example, if the waste solid on yarn is reduced, this means that more yarn can be put on the loom beam for weaving; or, that more yards of yarn can be slashed with the same quantity of size; or further yet, that loom efficiency is increased due to less waste on the yarn, and more yarn material goes through in the same amount of time. As a result, an economic benefit follows.

On the other hand, possibly inertia, or sunk cost of piping investment, influenced this plant not to change piping flows. As a result, potential use of a heat exchange system was not implemented.

At one time the plant had stopped using acetic acid as an agent for reducing the pH of their dye wastes, due to its heavy BOD waste load. Later the plant returned to using acetic acid, possibly as a result of the reduction in BOD resulting from the use of CMC. By returning to the use of acetic acid, the BOD load of the plant increased to approximately 60% of what it had been prior to the utilization of CMC. The advantage of using acetic acid is in its ability to increase the solubility of dye in water, besides reducing the pH factor.

Miscellaneous

Several further instances of in-plant process changes deserve mention. Recovery of chemicals has proven to be economical without regard to water pollution effects in the case of zinc (from zinc sulfate) and sodium sulfate.

In one instance water pollution considerations stimulated the substitution of another chemical for chromate in the treatment of water flowing through cooling towers. The substitute chemical did not perform as
effectively as chromate in retarding scale formation on equipment within
the plant, but it did alleviate a water quality problem in the small re-
ceiving stream that carried the company's wastes.

Additional Comments Regarding Plant Water Utilization Experiences

Process Changes vs. Waste Treatment. -- It is interesting to note that a
search of the chemical literature concerning warp-size wastes by Dr. H. Y.
Jennings at the Department of Textile Chemistry, North Carolina State Uni-
versity, indicated that practically no effort to abate pollution has taken
place in the area of recovery and re-use.

One textile executive felt that changes in production processes would
not be significant enough to warrant any great effort at change. The
problem apparently is viewed as one in which treatment is added as needed
to meet stream standards.

Stream Flow Augmentation. -- The projected New Hope Reservoir in the Cape
Fear Basin has planned flow augmentation as one of its benefits. However,
this augmentation will not be used in lieu of waste treatment for existing
plants along the river. The augmentation is planned so that increased
development and utilization downstream can occur in the future. One
aspect of the economic question is whether the benefit from augmentation
is greater than the cost of treatment that otherwise would have been
necessary to preserve stream usage.

In terms of plant locations and future plants locating, the flow
augmentation implemented policy for industry is described.

Suppose plant A is located to take advantage of flow augmentation
and an identical plant B is located without advantage of flow augmentation.
Plant A might require no waste treatment because of the added assimilative capacity of the flow augmented stream on its location. In such a case, plant B suffers due to the advantage gained by plant A. The profit margin of plant B is reduced accordingly unless price magically rose due to the additional cost.

However, State regulatory policy has tried to deal equitably with the upcoming New Hope augmentation plans. An example best explains the situation:

(1) At present x-level of production, secondary treatment already handles the waste effluent with y-pounds of BOD effluent discharged to the river.

(2) In two years, x-level of production will increase, secondary treatment still adequate for handling the waste.

(3) In five years, x-level of production will increase again, but now the natural resource capacity of the stream would be over-extended, as the 7-day-10-year minimum flow of record would not offer sufficient assimilation of wastes. However, with flow augmentation this additional effluent can be assimilated. Thus the future water resource demands of developing industry have been considered, without giving plants located on the stream the augmentation immediately in lieu of waste treatment.

A consultant dealing with a large array of textile plant water problems indicated three primary outfalls for classifying new plant wastes:
caustic, wash, and heavy, plus possible chemical reclamation of caustic. Re-use should come into considerable emphasis in the future.

**New Plants vs. Old Plants.** -- In some old plants the piping problem may be too immense for piping changes to be a worthwhile investment. Needless to say, the old plant represents a sunk investment which does not find such changes worth implementing to gain any practical economic benefit. Marginal economics possible in production process changes are negated due to past investments.

Additional comments with respect to old and new plants have been noted. New plants tend to segregate their wastes to a greater degree, while older plants run their wastes through a common mass. Newer plants have implemented counter rinsing and counter dyeing. New plants have implemented controls on water releases in their designs. New plants tend to move to better water dilution locations and where greater land area is available; topography and area characteristics of older plans are more likely to be poorly adapted to water pollution abatement. The new plant exposes more piping to achieve greater flexibility and accessibility. And newer plants have been able to implement heat exchange benefits more easily in their processing. Early planning did not consider needs of growth sufficiently nor designs with water concerns specifically in mind.

**Water Costs.** -- It is important to keep plant personnel aware of costs of water used in processing and treatment plant systems. Part of the problem is that the cost of water per unit of production is quite low so that the total effect on costs can apparently be neglected. It may be fairly safe to generalize from preliminary evidence that water costs
of a plant are likely to be less than 5 per cent of total costs of production. In terms of cost per yard of production, no plant quoting such costs stated their costs above a fraction of $\frac{1}{4}$. It is difficult to determine the particular costs as related to the separate production processes of a plant.

**Sizing Materials.** -- A survey of twelve size-manufacturing firms in the United States, by R. N. Berrier of North Carolina State University, indicated that plants using starch size could not foresee any way of recovering the size. Textile companies that had substituted synthetic size for starch were interested in recovery of their materials, while the low BOD properties had been giving them no trouble with water resources authorities. Plants that had already installed water treatment plants were satisfied with using low-priced sizing materials and treating the waste as needed. Plants using synthetic fibers and fabrics felt that their volume of sizing materials was so insignificant that the problem was not serious for them.

Berrier concluded from his inquiry that plants felt no real problem unless their product, location, or processes, or water resource authority forced them to do something about the problem.

**Location Consideration.** -- In addition to process and treatment alternatives, location determines the degree of the pollution problem as applied to those two alternatives. That is, the assimilative capacity of the receiving stream is important. For example, three large firms involved in textiles come to mind. Each of these firms has plants located on streams of differing assimilative capacity. In turn, one's pollution treatment pressures have been less due to large stream cfs flow. A second's pressures are relatively greater due to a lesser cfs flow, while a third's problem was evident early in its history as the receiving stream was of little help in terms of cfs flow. This firm has invested heavily in treatment measures.
Summary and Conclusions

The case studies included in this report were directed at providing a better understanding of the water pollution problems of some typical individual textile plants in North Carolina. No effort was made to consider the performance of textile mills in a systems context -- such as, the inter-action of a series of mills and municipalities in one river basin. It is likely that systematic studies of this nature would provide useful insights, but time did not permit such an analysis here.

Two special analytical problems were encountered in the course of this project. One involved the unique characteristics of most individual textile mills and the diversity and complexity of the industry. Because of these factors it is difficult to generalize about water pollution abatement in the textile industry. The other analytical problem involved limited availability of data concerning water problems in the mills that were studied. In very few instances does existing plant accounting permit accessibility to information on water use and costs.

Effect of State Regulation of Water Pollution. -- It seems likely that, until at least 1950, economic motives were the only effective stimulus for water pollution abatement resulting from process changes in North Carolina textile mills. Such waste treatment facilities as were installed probably resulted from unusual pressures of local public opinion.

With the establishment of the State Stream Sanitation Committee* in the early 1950's, the first substantial official constraint external to the plant had become a reality.

* The Stream Sanitation Committee was merged with the Board of Water and Air Resources in 1967.
With the coming of the SSSC, the economic and legal forces began to act jointly. As the textile industry slowly began to take cognizance of that body, the issue influenced the internal creation of waste effluent that had previously flowed unrestrained into the receiving streams of this state. What had been previously economical for a plant to do -- let its pollution effluent enter receiving streams -- now had become recognized as uneconomical for society, a cost to society for which the plant must now bear some responsibility.

Along with the growing force of the SSSC, especially in the 1960's, textile plants began to take another look at the potential economic benefits possible. The plants were becoming educated to the responsibility of social welfare or benefit. In the meantime citizen interest in water and environmental pollution grew, and provided additional stimulus for increased textile mill pollution abatement activity.

The Nature of Water Pollution Problems in Textiles. -- Several factors should be noted initially in defining the nature and extent of water pollution problems in the textile industry.

Most of the serious water pollution problems caused by textile mills arise in the dyeing and finishing sector of the industry, a relatively small segment of the textile industry taken as a whole. In 1979 the finishing and dyeing sectors accounted for only about % of textile employment and value added in North Carolina.

In addition, water-related costs in the wet-process textile plant are usually assumed to be only a minor part of total production costs of the plant. This means that economic incentives may be lacking for changes in water using processes that might help abate pollution. Herein lies one of the pertinent realities of the water pollution problem in the textile industry.
There are many small plants whose handling of water is less attuned to the latest developments. Meanwhile the larger integrated firms do more scheduling of their programs, including water pollution problems. The small plant may lack economies of scale that would otherwise give them incentives to make more water-related changes.

Relating Process Changes and Waste Treatment Facilities. -- The findings of this study indicate that even the most efficiently engineered textile wet-processing plant equipped with the most advanced methods of conserving water and reducing effluent, would still require some treatment of the final process effluent.

If a least-cost solution is to be achieved, it is necessary to relate the production process costs, BOD effects involved with each change, and the resulting effects on treatment plant size and costs. In this way a minimum investment may more closely be reached while considering needs to reduce BOD in physical terms. A fuller appreciation of the technological and economic interrelationships should result.

It has been urged by some experts that changes should be made first in the production processes, with treatment being installed as a last resort. However, it appears that more generally the textile plant has turned immediately to the treatment alternative for solution without consideration of possible changes in production processes. Ideally one would like to reach a least-cost investment by exhausting both areas of alternatives. The expense of such investigations and the sunk investments incurred through the years may deter this effort. Perhaps the ideal arrangements can be applied only to the plant that is to be built in its entirety in the future. Then perhaps the opportunity cost ideal will more nearly be realized by the plant.

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**Age-of-Plant Factor.** -- This study has evidenced significant differences between older plants and relatively new plants regarding the economics of water use. There is a strong likelihood that most changes in production processes are not made in existing plants because capital expenditures and layout have already been incurred through the years.

Perhaps the greatest obstacle to change that faces the old plant is that of piping and design of plant. In most cases the management of the older plant was not aware of the future pollution concerns that were to become the focus of public attention. With its basic investment already made, it has not been economical for the plant to make changes its management might otherwise like to make. Often the plant has expanded through the years in a rather patchwork fashion, without concern for its piping, its over-all design, or for the purposes of better handling its water problems.

**The Location Factor.** -- In addition, the location of the plant has been to its benefit or to its loss, depending upon such considerations as topography, area, and receiving stream flow associated with its location. Such qualities have determined to what extent the economic impact of stream pollution safeguards by society have affected that plant. Such qualities have predetermined what resulting treatment plant has become the most economical to install under such constraints.

Reuse of process water may become much more intensively practiced in the future in the textile industry. Again, this may depend a great deal upon whether the plant is basically reacting to the constraints it faces and little more. Or, the plant may be planning ahead in anticipation of potential problems that lead to a serious consideration of water reuse.

It is a basic fact that waste treatment plant costs increase significantly as higher percentages of treatment are attained. This factor may
play some part in future considerations toward reuse of plant water when faced with a stream of "shrinking" future assimilative capacity. Of course, the more a plant goes to reuse of its process water, the less dependent it will be upon assimilative capacity of the stream or upon potential change of stream usage by society.

Naturally, if recovery or elimination of desize wastes could be engineered, a great deal of the pollution load in BOD terms and in economic impact would be eliminated.

Finally, it may be pointed out that no consideration in this study has been given to the relationships of water pollution and air pollution. These relationships may become increasingly important, especially in larger industrial areas of concentration. In essence, a water pollution problem may be turned into an air pollution problem if wet wastes are retained, dried, and burned so that they enter the atmosphere; or vice versa, if air pollutants are "washed" with resultant waste waters.

**Importance of Vi\*le State Controls.** -- The case study concerning the projected Fiber Industries plant in Orange County illustrates the stake of the textile industry -- and indeed of all industry -- in a viable and effective state water pollution control program. Real or imagined weaknesses in the protection afforded by the state program to any important group of water users are likely to be exploited to the disadvantage of industries which have made their plans for waste treatment facilities in reliance on the stability of state regulations. As Fiber's experience demonstrates, this can even happen to conscientious firms which have made every reasonable effort to comply with the spirit as well as the letter of existing regulations. And, as Fiber's experience also demonstrates, water quality management cannot be viewed in a vaccuum. If related issues (such as land use decisions) are not satisfactorily resolved, the foundations of the strongest water pollution control programs may be undermined.