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***State of
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***Department of Environment
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Division of Waste Management
Superfund Section***

***COMBINED PRELIMINARY ASSESSMENT / SITE INSPECTION
REFERENCES***

***Virginia Carolina Chemical – Wadesboro
NCSFN 0406 924
Wadesboro, Anson County, North Carolina
Reference No. 06754***

December 30, 1999

***Scott C. Ryals
Environmental Chemist
Division of Waste Management
Superfund Section***

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LATITUDE AND LONGITUDE CALCULATION WORKSHEET #2
LI USING ENGINEER'S SCALE (1/60)

SITE NAME: VC Chemical - Wadesboro CERCLIS #: NCSTN 0406 924

AKA: _____ SSID: _____

ADDRESS: Starbuck Ferry Rd

CITY: Wadesboro STATE: NC ZIP CODE: _____

SITE REFERENCE POINT: North edge of Fire Pond

USGS QUAD MAP NAME: _____ TOWNSHIP: _____ N/S RANGE: _____ E/W

SCALE: 1:24,000 MAP DATE: 1956/1978 SECTION: _____ 1/4 _____ 1/4 _____ 1/4

MAP DATUM: 1927 1983 (CIRCLE ONE) MERIDIAN: _____

COORDINATES FROM LOWER RIGHT (SOUTHEAST) CORNER OF 7.5' MAP (attach photocopy):

LONGITUDE: 80° 00' 00" LATITUDE: 34° 52' 30"

COORDINATES FROM LOWER RIGHT (SOUTHEAST) CORNER OF 2.5' GRID CELL:

LONGITUDE: 80° 02' 30" LATITUDE: 34° 57' 30"

CALCULATIONS: LATITUDE (7.5' QUADRANGLE MAP)

A) NUMBER OF RULER GRADUATIONS FROM LATITUDE GRID LINE TO SITE REF POINT: 156

B) MULTIPLY (A) BY 0.3304 TO CONVERT TO SECONDS:

$$A \times 0.3304 = \underline{51.54}''$$

C) EXPRESS IN MINUTES AND SECONDS (1' = 60"): _____ , 52 "

D) ADD TO STARTING LATITUDE: 34° 57' 30" + 52 =

SITE LATITUDE: 34° 59' 22"

CALCULATIONS: LONGITUDE (7.5' QUADRANGLE MAP)

A) NUMBER OF RULER GRADUATIONS FROM RIGHT LONGITUDE LINE TO SITE REF POINT: 169

B) MULTIPLY (A) BY 0.3304 TO CONVERT TO SECONDS:

$$A \times 0.3304 = \underline{55.84}''$$

C) EXPRESS IN MINUTES AND SECONDS (1' = 60"): _____ , 56 "

D) ADD TO STARTING LONGITUDE: 80° 02' 30" + 56 =

SITE LONGITUDE: 80° 03' 26"

INVESTIGATOR: Scott C. Lynch DATE: 10/20/99

TECHNICAL PAPER NO. 40

RAINFALL FREQUENCY ATLAS OF THE UNITED STATES

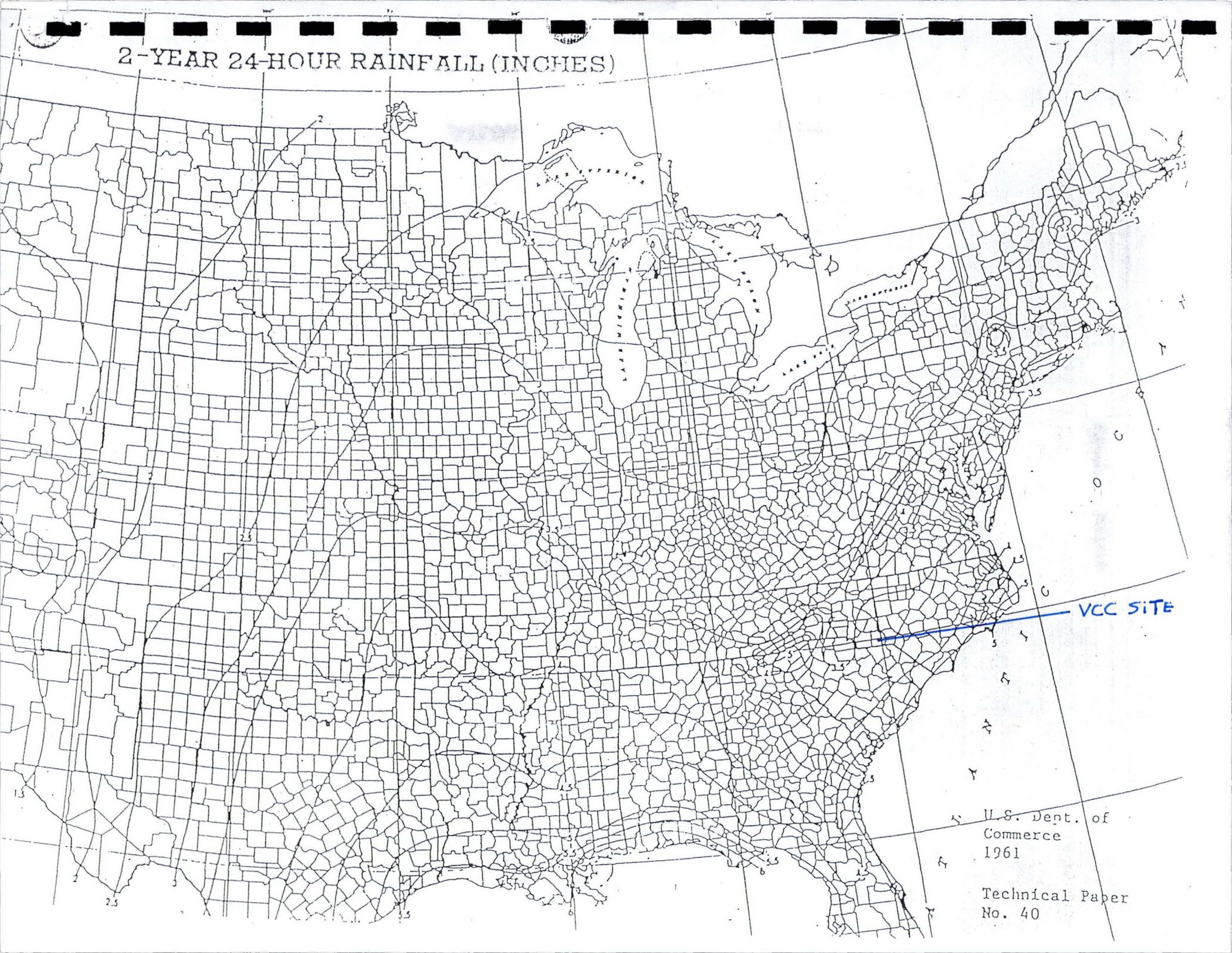
for Durations from 30 Minutes to 24 Hours and
Return Periods from 1 to 100 Years

Prepared by
DAVID M. HERSHFIELD
Cooperative Studies Section, Hydrologic Studies Division
for
Engineering Division, Soil Conservation Service
U.S. Department of Agriculture



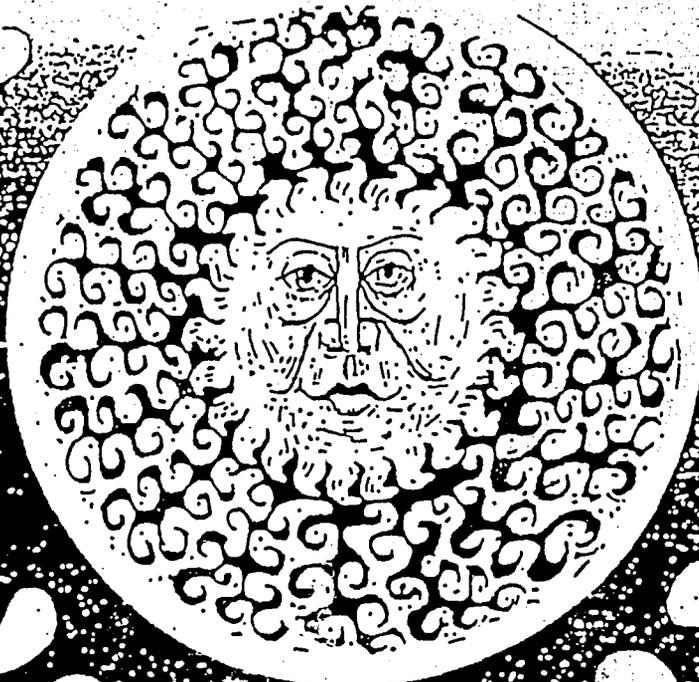
PROPERTY OF EPA
FIT IV

2-YEAR 24-HOUR RAINFALL (INCHES)



U.S. Dept. of
Commerce
1961

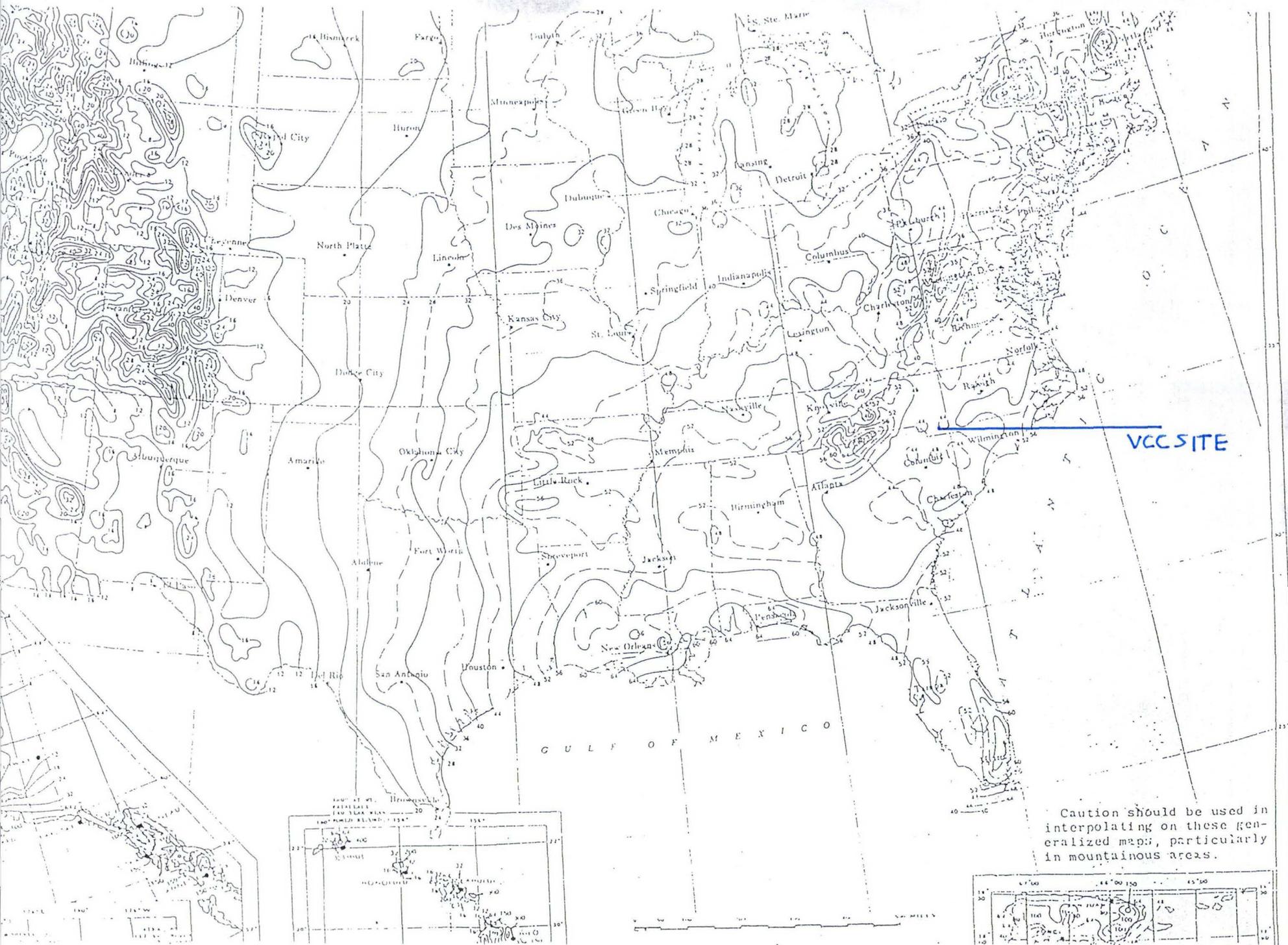
Technical Paper
No. 40



CLIMATIC ATLAS OF THE UNITED STATES

PCCE . Environmental Science Services Administration . Environmental Data Service

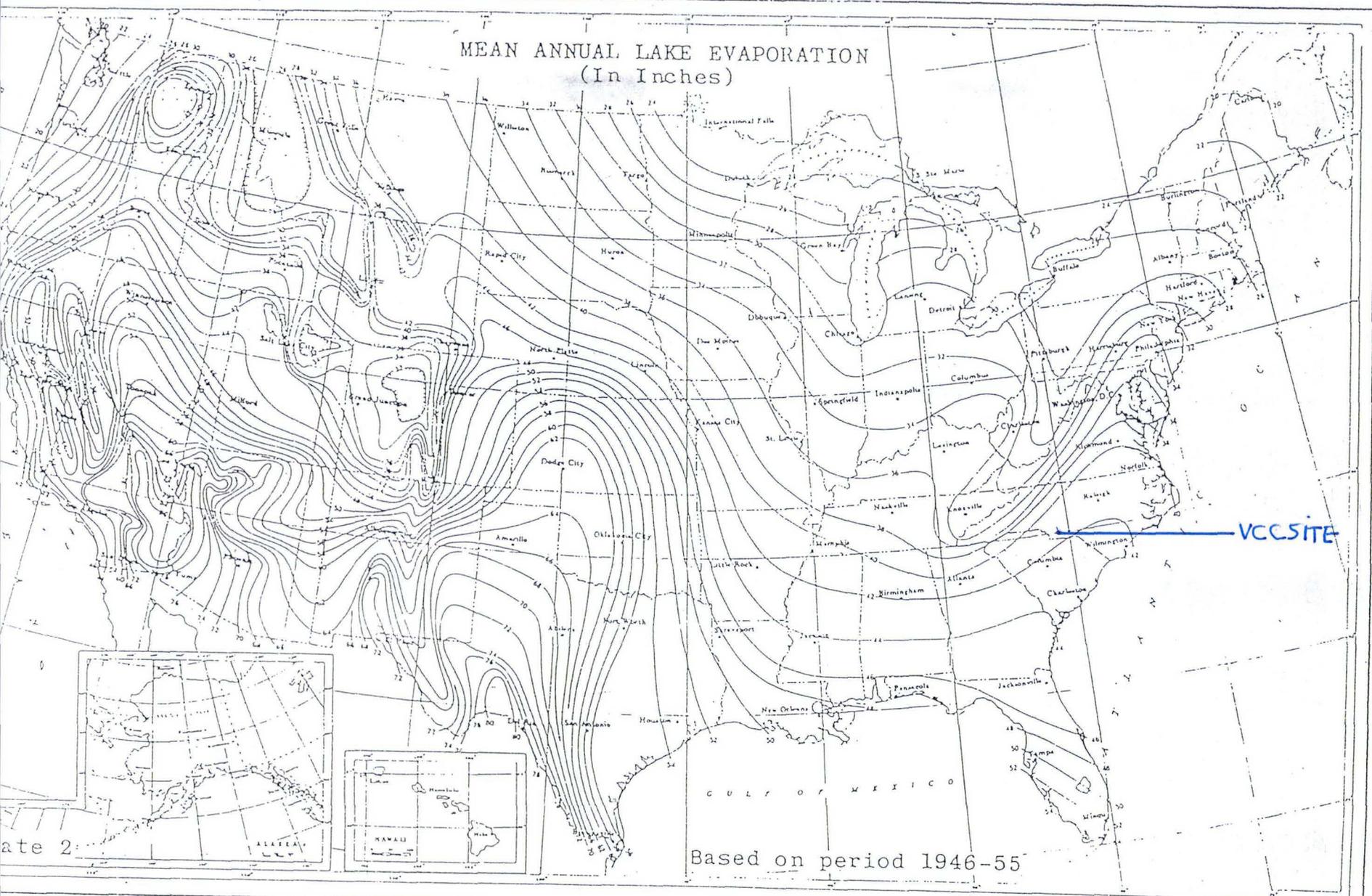
NORMAL ANNUAL TOTAL PRECIPITATION (INCHES)



VCC SITE

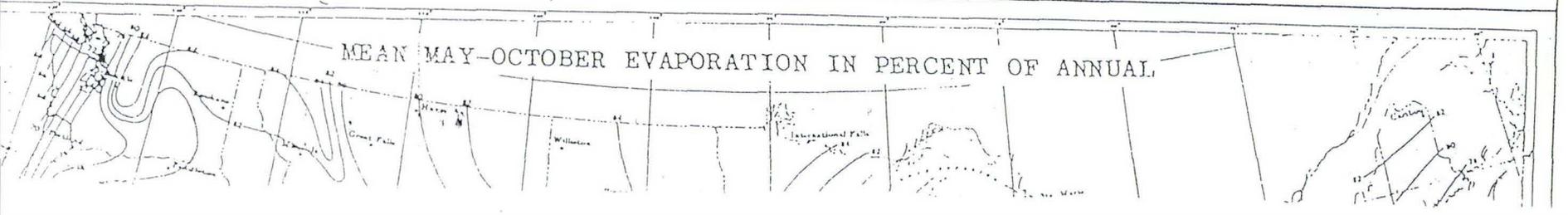
Caution should be used in interpolating on these generalized maps, particularly in mountainous areas.

MEAN ANNUAL LAKE EVAPORATION (In Inches)



Based on period 1946-55

MEAN MAY-OCTOBER EVAPORATION IN PERCENT OF ANNUAL



For example, it contains 20 farms of 1,000 or more acres, and 15 farms have an annual income of more than \$25,000. The farm tenancy rate is 43.3 per cent.

Forests Survive

A county as old as Anson, and cultivated so long and closely, suggests endless fields and pastures. But as a matter of fact, over half the acreage is still in timber, and the cutting of pulpwood is one of the major sources of farm income. For some years, wood-using industries, especially paper concerns, have been buying up Anson land to add to their reserves, a process which has caused some shrinkage in the number of farms.

They do so with good reason, for Anson's soil is excellent for trees. In the eastern sands it is slash pine, in the western clay it is loblolly, and both, as an official put it, "make the pines jump right out of the ground." The area around White Store is especially favorable, and some fine forests were observed in this region.

The lumber industry had several periods of prosperity. In 1917, it was quite active again, with old field pines fetching good prices and increasing value of land.

When the Civil War came, Anson was fixed in a pattern more like that of the Deep South cotton country than of Piedmont North Carolina. Only a few industries had been developed, but large plantations had brought prosperity to some families who lived in comfort and even luxury. In 1860, there were 6,832 slaves, 101 free colored and 6,556 white residents.

Civil War

Anson was enthusiastic about the Confederacy. It hoisted its own secession flag prematurely and sent 1,182

men to the army. And it suffered correspondingly by defeat. Sherman's bummers burned and pillaged. Over half the tangible property of the citizens was wiped out by emancipation, and reconstruction was a time of depression and despair.

Railway Arrives

Anson paid little attention to anything except agriculture for the first century and a quarter of its existence. A prerequisite of industry — transportation — got a start in 1861 when tracks were laid for the old Carolina Central, but it was 1874 before trains reached Wadesboro. Since then Anson has obtained service from the Seaboard, Atlantic Coastline and the Winston-Salem Southbound. Twenty-one major truck lines operate in the county.

Then in the 80's, the presence of so much cotton suggested the obvious — a cotton mill. In 1890, the Wadesboro Cotton Mill — the first locally owned industrial plant in Wadesboro — was opened. In the same year the first silk mill to be built in the South was located at Wadesboro by George and Robert Singleton of Dover, Delaware. It operated into the first quarter of 1900. A full decade passed before another industry was realized, this one also derived from its great crop. The Wadesboro Cotton Oil Company was established.

Industrial Awakening

But little else stirred the county. A contemporary writer said Wadesboro's streets were "ankle deep in sand," civic equipment was inadequate or lacking. Arrival of the Winston-Salem Southbound railway gave the county three railroads — an enviable asset — and in 1911 came the plant of Virginia-Carolina Chemical Company, and ten



This is the 6th courthouse (dedicated in

years later Anson began to awake

Small businesses sprang up, meetings were held, a chamber of commerce organized. A water system installed in the county seat, a swift order came a new post office, high school, courthouse and theater.

Another textile plant was organized — the Wade Mill employing 325 — the large plant for that day. Two lumber mills followed and the community up a fund for investment in an industry planning to locate.

Power Development

The largest single development to come to Anson County, and leading to other industrial expansion of the section, was building of power dam at Blewetts Falls. Here a narrow gorge, William Bluit (ett) had a profitable ferry and fish. And here Hugh MacRae of Wil

MEMO

TO: Staff
DATE: January 29, 1999
FROM: Jeanette Stanley, Environmental Chemist
NC Superfund Section
SUBJECT: Fertilizer Manufacturing Facilities
Contaminants of Concern



I have reviewed the sulfuric acid manufacturing chapters in two Chemical Engineering texts dated 1928¹ and 1941², and Kirk Othmer³. The manufacture of sulfuric acid was a central part of the fertilizer manufacturing process. The purpose of this review was to determine which contaminants would be associated with the various structures, features and processes shown on the Sanborn maps of old fertilizer manufacturing facilities. Sulfuric acid was used to acidulate phosphate rock. Fluoride is a component of phosphate rock, and the acidulation process results in the formation of **hydrogen fluoride and fluorine gas**.

In the eighteenth and nineteenth centuries and up to the turn of the century, the **chamber process** was the most widely used method of manufacturing sulfuric acid. **Iron pyrite (fool's gold)** was the most common raw material for sulfur compounds. The pyrite was burned/roasted in brick-lined fire boxes of varying designs. In addition to **iron pyrite**, this raw material also contained **arsenic and selenium** with some **copper, nickel, cobalt and gold**. If a plant used pyrite, it is almost certain that these contaminants will be found in the vicinity of the pyrite burners, pyrite storage areas, and areas of spent pyrite disposal. The acid stream also contained these contaminants. By 1920, 80% of the factories burned fairly pure sulfur, so facilities that only burned **sulfur** may not have these contaminants. Due to its corrosion resistance, **lead was used as a construction material** at all of these old plants. Very little lead is used in fertilizer plants today.

After pyrite or sulfur burning, the hot sulfur oxide gases were transferred to the bottom of and rose through the Glover Tower and then sent to the lead chambers. Sulfur oxides, water, and oxides of nitrogen (produced from a separate ammoniation step) were combined in the lead chambers (usually of series of three to six chambers) to make sulfuric acid. **Lead chambers** were typically rectangular vessels, constructed of sheet lead with dimensions ranging from 50 - 150' long, 16 - 26' high, and 20 - 30' wide. There were usually three - six chambers. A portion of the acid condensed on the chamber walls, drained into a gutter constructed inside the chamber and **dripped from a spout outside the chamber**. Observation of this fluid gave the plant operators information in order to operate the plant. Overland pathways leading from the lead chambers will likely show high levels of lead. By 1941, several variations of this basic chamber design were tried throughout the US to facilitate mixing and contact, the most popular of which was the Mill-Packard system that used a series of truncated cones, 7,000 to 18,000 cubic feet each. All design variations of the chamber process discussed in these references still used lead as the construction material.

After leaving the lead chambers, the acid was then trickled down the **Glover Tower** (countercurrent to the rising, incoming gases), and thereby concentrated. The **Glover Tower** was constructed of acid-proof brick, with or without a **sheath made of lead**. The Glover Tower rested on a **lead pan**, and on top of the lead pan was laid an acid-proof masonry floor. The tower was packed with a **coarse material such as quartz gravel**. The packed section of the Glover Tower was 30 - 40' high.

After leaving the Glover Tower, the acid was typically cooled in water-jacketed lead tubs filled with lead cooling coils. Another tower associated with the process, the Gay-Lussac Tower, served to recover oxides of nitrogen from the exhaust gases. Facilities usually had two 35'-tall Gay-Lussac Towers next to each other. Lead was not typically used as a construction material in the Gay-Lussac Tower. The ammoniation facilities were usually constructed of cast iron. Platinum catalysts have been used in the ammoniation step since about 1926. Heat exchangers containing ammonia usually were constructed of nickel or aluminum.

The contact process was minimally used prior to 1928 and was used to a greater extent by 1941, mostly to make high purity sulfuric acid. (By World War II, the chamber process was practically obsolete.) Platinum or vanadium catalysts were used for the reaction process. Due to the vulnerability of platinum catalysts to poisoning by contaminants (arsenic and halogens) in sulfur oxide gases derived from pyrite, contact process plants eventually used sulfur for the raw material. Even so, a lead-lined box filled with coke was used to filter out the contaminants in the gas stream. The contact process usually included additional acid scrubbing towers. Vanadium catalysts were introduced in the US in 1926. Vanadium was inexpensive and relatively free from poisoning effects, but the expense due to licensing and patents caused the continued use of platinum. By WWII, platinum catalysts had been mostly phased out. Support matrices for the catalysts, such as asbestos and magnesium sulfate were likely disposed of on the sites during catalyst regeneration.

Even though the lead chambers were not longer used in the contact process, the contact process used lead in the filter boxes, Glover Tower, and cooling coils and boxes. Drips from these coolers, scrubbers and filters were collected and recirculated, so the level of lead contamination may not be as high as that found at chamber process plants. Contaminants expected in connection with the contact process include lead, platinum, and vanadium. Since most of the catalysts were recovered and recycled due to their value, it is not expected that large quantities of catalyst materials will be found. Support matrices for the catalysts, such as asbestos and magnesium sulfate may be found on these sites.

¹Badger, W. L. And E. M. Baker, *Inorganic Chemical Technology*, McGraw-Hill Book Co., Inc., New York and London, 1928, pp. 39 - 78 and 1941, pp. 37 - 75, respectively.

³Kirk Othmer, *Encyclopedia of Chemical Technology*, Third Edition, John Wiley & Sons, 1983, "Fertilizer Manufacturing", Vol. 10, pp. 31 - 32 And "Sulfuric Acid", Vol 22, pp. 190, 191, 220.

MANUFACTURING PROCESS FOR "SUPER-PHOSPHATE FERTILIZER"

Phosphate is stripped from low-grade, phosphate-rich rock, using sulfuric acid. Sulfuric acid is processed from pyrite and arseno-pyrite ores originally imported from Spain and England. The ores were brought in by barge and delivered to manufacturers by rail. Iron pyrite (i.e. FeS_2), or "Fool's gold", is often mixed with small quantities of copper, arsenic, nickel, cobalt, selenium and even very trace amounts of gold, depending upon the source of the ore.

In the early 1900's, sulfuric acid was commonly processed utilizing the lead chamber method. In this method, sulfides such as the iron pyrite or "pyrite", copper or chalcopyrite (CuFeS_2), and arseno-pyrites were heated to produce sulfur dioxide, leaving iron, arsenic, copper and other heavy metals as a by-product. The sulfur dioxide was then mixed with air, steam, and nitric oxides as catalysts in lead-lined brick chambers, producing sulfuric acid. Sulfuric acid, added to finely ground low-grade, phosphate-rich rock, would produce "super-phosphate", releasing fluorine (gas) in the process.

Besides pyrite ores, elemental sulfur could also be mined from various ores and roasted to yield sulfur dioxide in making the sulfuric acid. A typical composition of the end product of "super-phosphate" fertilizer would be as follows: $\text{CaH}_4(\text{PO}_4)_2 \cdot \text{H}_2\text{O}$ at 30%, CaHPO_4 at 10%, CaSO_4 at 45%, Silica at 10%, Water at 5%, iron oxide and alumina.

Iron and copper compounds remaining from the roasting of the sulfides would produce the "reddish" or magenta color to the waste byproducts. Other heavy metals, such as arsenic, cobalt, selenium, and mercury, would be concentrated in the wastes as well. The presence of lead in the wastes is from the acid leaching of the lead-lined brick chambers.

The lead chamber method or "chamber process" is an obsolete practice for manufacturing sulfuric acid and is no longer used in the United States. Virginia-Carolina Chemical Company and Barker Chemical Company were two manufacturers who used this process in the early 1900's.

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CHEMICAL ENGINEERING SERIES

INORGANIC CHEMICAL TECHNOLOGY

BY

W. L. BADGER

Manager, Consulting Engineering Division, The Dow Chemical Co.

AND

E. M. BAKER

Professor of Chemical Engineering, University of Michigan

SECOND EDITION
SECOND IMPRESSION

McGRAW-HILL BOOK COMPANY, Inc.

NEW YORK AND LONDON

1941

CHAPTER III SULFURIC ACID

Sulfuric acid is the most important product of the inorganic chemical industries. It enters into so many different processes in large amounts that the sulfuric acid market may be considered a better barometer of business conditions than even the iron and steel market. This is not only because sulfuric acid has fully as many applications as iron and steel, but also because, since it is rarely stored, its production and consumption respond more quickly to changes in business activities. Sulfuric acid not only represents the condition of manufacturing industries, but because of its use in fertilizer manufacture it is equally significant as a barometer of agricultural conditions. It has even been said that the industrial development of any country can be measured by its consumption of sulfuric acid.

The technology of sulfuric acid is remarkable in that the chamber process has been operated for seventy years with practically no significant changes in equipment and method beyond those that were made at the very beginning. In the last 20 years, with a better understanding of such unit operations as combustion, fluid flow, heat flow, gas absorption, and the mechanism of heterogeneous reactions, a number of attempts have been made to redesign the old chamber process in the light of this new knowledge. Only one of these modifications, the Mills-Packard, has had any appreciable acceptance beyond the initial plants built by the respective inventors. Probably one reason for the failure of the industry to adopt the newer engineering ideas in chamber plants is that it is generally recognized that the future of this process, even with these improvements, is decidedly questionable. Existing chamber plants will probably continue to operate as long as it is economical to run them, and will then be superseded by contact acid plants.

Production and Distribution.—The production of sulfuric acid in the United States in 1940 was equivalent to 9,150,000 short

tons of 50°Bé. acid. This was distributed amongst the various uses as follows:

TABLE VII.—USES OF SULFURIC ACID

	Per Cent
Fertilizers.....	24.7
Petroleum refining.....	13.9
Iron and steel.....	13.2
Chemicals.....	11.9
Coal products.....	9.8
Other metallurgical.....	7.0
Paints and pigments.....	6.2
Rayon and cellulose film.....	5.1
Explosives.....	1.9
Textiles.....	1.4
Miscellaneous.....	4.9

The enormous consumption of acid in the fertilizer industry usually results in acid plants and fertilizer plants being in the same locality. In many cases, the acid plant is operated by the fertilizer factory. The fertilizer plant ordinarily uses acid of 50°Bé. and is, therefore, supplied directly with this dilute acid. Other industries either need concentrated acid, or need small enough tonnages so that they may purchase concentrated acid and dilute it. Hence, they do not need to be located at producing centers. The manufacture of explosives, and some branches of the chemical industry, use acids of extremely high strength and may operate their own plants to produce these.

Sulfuric acid is ordinarily sold as 50°Bé. or chamber acid (62.18 per cent H_2SO_4), 60°Bé. acid (77.67 per cent H_2SO_4), and 66°Bé. acid, or oil of vitriol (93.19 per cent H_2SO_4). Acids stronger than 66°Bé. are usually spoken of by their per cent acid concentration, and 100 per cent sulfuric acid is commonly called monohydrate.

Sulfur trioxide dissolves in monohydrate to give fuming acids or oleums. The strength of these may be expressed in various ways. An acid containing 20 pounds of free SO_3 dissolved in 80 pounds of H_2SO_4 might be spoken of as 20 per cent oleum, or as acid containing 85.3 per cent total SO_3 . If to 100 pounds of this mixture sufficient water (4.5 pounds) be added to combine with the free SO_3 , there will result 104.5 pounds of 100 per cent H_2SO_4 . From this point of view such acid would be called 104.5 per cent acid.

RAW MATERIALS

The earliest commercial raw material for the manufacture of sulfuric acid was sulfur from Sicily. Later many plants turned to iron pyrites (FeS_2) as their raw material. This trend increased until at the beginning of the present century the larger proportion of sulfuric acid made in this country was made from pyrites. When cheap sulfur of high purity from American sources became available, more and more plants turned to sulfur, until in 1920 about 80 per cent of the acid made in this country was made from sulfur. The margin of cost between the two raw materials is small, and for some years the balance between these costs has resulted in making a gradually increasing percentage of the total from sulfur.

Sulfur.—Before 1900, the world's production of sulfur came entirely from deposits in volcanic regions, the most important of which was in Sicily. Sulfur was mined in the form of a porous rock that contained up to 40 per cent free sulfur. The methods employed were crude and usually consisted in piling the ore in heaps, starting a fire at the bottom, and allowing the heat from the combustion of part of the sulfur to melt the rest, which was collected in molds below the heap. The recovery was incomplete and in recent years more economical apparatus has been used. Even so, the yield is small and the cost high. A small amount of sulfur was imported into the United States as late as 1916 but since that time there have been practically no imports.

The producing areas in the United States consist of a few scattered deposits, each covering a relatively small area, in the Louisiana-Texas coastal plains. Each of these deposits lies above an anhydrite layer cap rock of a salt dome. Although these deposits were known in 1865, it was not until the development of the Frasch process in 1891 that production was possible. The Frasch process was so successful that in a relatively short time it was producing almost all the sulfur used in this country.

In these deposits, sulfur occurs distributed through a limestone rock, which is covered by thick layers of alluvial deposits and quicksand that effectively prevent its recovery by ordinary mining methods. The Frasch process^(1,2,3) consists in pumping highly heated water into the rock to melt the sulfur, and then

raising the melted sulfur to the surface with an air-jet lift. A 10- or 12-inch hole is drilled to the sulfur-bearing layer and cased to

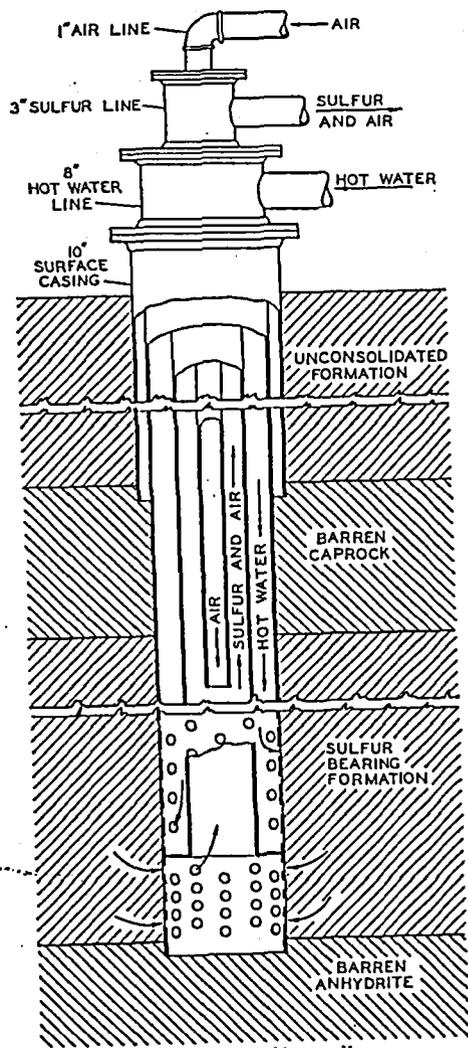


FIG. 11.—Sulfur well.

the surface of the rock (Fig. 11). Inside this casing are three other concentric pipes, about 8, 3, and 1 inch, in diameter respectively.

The 8-inch pipe is perforated where it passes through the sulfur-bearing layer. Water superheated to 300 to 320°F. is pumped

down between the 3-inch and the 8-inch pipe and flows into the sulfur-bearing stratum. The molten sulfur collects in a pocket at the bottom of the 8-inch pipe. Compressed air sent down the 1-inch pipe lifts the sulfur to the surface in the 3-inch pipe. The water is removed through bleed wells located around the outer edge of the area to be worked. The sulfur-air mixture is discharged to shallow pits from which the molten sulfur is pumped to large plank bins, where it solidifies.

These blocks of sulfur, which may contain several thousand tons, are later broken up with explosives and shipped. The sulfur so produced is 99.5 to 99.8 per cent pure and is free from arsenic and selenium but does contain small amounts of asphaltic material and incombustible residue.

The effect of the Frasch process on the situation in the United States is strikingly pictured in Table VIII.

TABLE VIII.—PRODUCTION OF SULFUR IN METRIC TONS

Year	United States imports	United States production	World production
1895	126,760	1,676	398,916
1900	167,328	4,630	581,282
1901	175,310	6,977	604,930
1902	176,951	7,565	552,996
1903	190,931	35,660	631,035
1904	130,421	196,588	767,249
1905	84,579	218,440	830,609
1910	30,544	259,699	787,732
1915	24,647	299,133	860,000
1920	44	1,542,059	1,941,052
1925	102	1,431,912	2,213,330
1930	29	2,558,981	3,091,709
1935	1,763	1,632,590	2,254,000
1939	14,000	2,091,000	2,900,000

In recent years, a beginning has been made in the production of sulfur as a by-product of various industries. Sulfur is now being produced in small amounts, but on an industrial scale, from sulfur compounds removed in the purification of nitrogen and hydrogen in the manufacture of synthetic ammonia; from various by-products obtained in the removal of sulfur compounds from coal gas; and by the reduction of sulfur dioxide with coke. This last proc-

ess is at present in operation at a copper-lead smelter at Trail, B.C.⁽⁶⁾ All of these methods combined do not produce an important amount of sulfur at present, but the production of sulfur from smelter gases seems to have appreciable possibilities, especially for smelters so located that they find it more economical to ship sulfur than to convert the sulfur dioxide into sulfuric acid and ship the acid to consuming points.

Pyrites.—Iron pyrites is usually represented by the formula FeS_2 and if pure should contain 53.4 per cent sulfur; but the mineral actually mined is variable in composition. Most manufacturers demand pyrites containing over 42 per cent sulfur. During the World War, material as low as 30 per cent sulfur was accepted. In 1937 the domestic production was about 50 per cent of the total consumption.

Other Raw Materials.—In the metallurgy of most of the non-ferrous metals there is a step that involves roasting a sulfide ore. This operation produces sulfur dioxide that might be used as a raw material for sulfuric acid manufacture. At present, however, this material is important only at zinc smelters, where considerable amounts of sulfuric acid are made from the waste gas from roasting zinc sulfide. In a few cases, sulfuric acid is made from the waste gas of copper smelters, but such plants are usually too far from consuming centers or else they produce gas so variable in composition as to be unsuitable for sulfuric acid manufacture.

In 1937 the relative production of acid in the United States from different sources was as follows:

	Per Cent
From sulfur.....	64.4
From pyrites:	
Imported.....	12.5
Domestic.....	11.9
By-product sources.....	11.2

CHAMBER PROCESS

Sulfuric acid may be made by several processes, of which the most important are the chamber process and the contact process. A general outline of the chamber process is given in Fig. 12, which is purely diagrammatic and indicates only the most important elements in the process. Sulfur is burned with sufficient excess air so that the concentration of oxygen is slightly greater than

that of sulfur dioxide. Nitric oxide, obtained by the oxidation of ammonia, is introduced into the gas stream. The gas mixture then passes to the base of the Glover tower, down which acid is flowing. The gas rises through this tower, concentrating the acid, thereby becoming cooled and picking up considerable water vapor. From the top of the Glover tower the gases are conducted to the lead chambers, of which there may be from

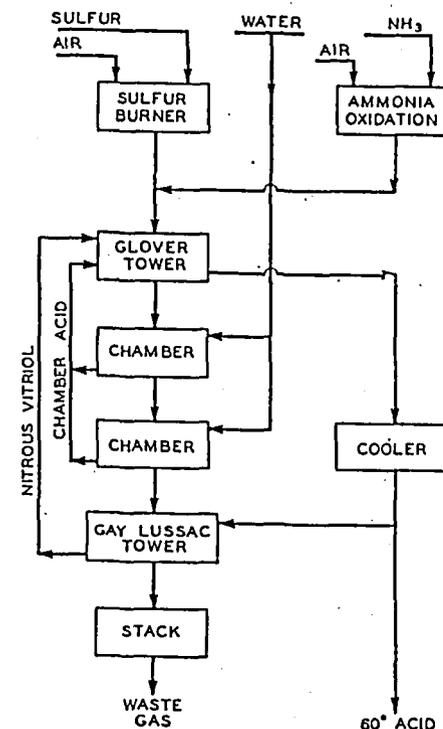


Fig. 12.—Flow sheet of chamber process.

four to eight, although only two are shown in the diagram. Intermediate towers may or may not be placed between the chambers. Water is introduced into the top of the chambers, either in the form of spray or steam. In the chambers sulfur dioxide, oxygen, water, and the oxides of nitrogen react to form sulfuric acid, which collects in the bottom of the chambers and is drawn off as chamber acid of about 50°Bé . At the end of its passage through the chambers, the gas has lost most of its

sulfur dioxide, but still contains oxides of nitrogen. These are recovered in the Gay-Lussac tower by absorption in a stream of cold 60° acid introduced at the top. The residual gas, consisting largely of nitrogen and oxygen, is discharged into the air from a stack.

The chamber acid is fed to the top of the Glover tower, and in its passage down this tower is concentrated to about 60°Bé. From the base of the Glover tower it passes through a series of coolers. Part of the cooled acid is drawn off as product, but a considerable proportion is sent to the top of the Gay-Lussac tower to absorb oxides of nitrogen. The acid drawn from the base of the Gay-Lussac tower is called *nitrous vitriol*. This is taken to the top of the Glover tower; and in its passage down through the Glover tower the oxides of nitrogen are displaced and returned to the gas stream. Consequently, oxides of nitrogen that are added merely serve to make up losses and are only a small fraction of the total amount of oxides of nitrogen in the system. If the plant produces only 50° acid, chamber acid is withdrawn as the principal product and is not sent to the Glover tower. In such cases, water is fed to the top of the Glover tower to supply the water that would otherwise be added in the form of chamber acid.

Sulfur Burners.—A successful sulfur burner must fulfill several requirements. As a consequence of the low heat of combustion and the high vapor pressure of sulfur, the burner must expose a large surface of molten sulfur; minimize loss of heat by radiation; provide secondary air in the zone of high temperature to burn sublimed sulfur; and facilitate the removal of non-combustible floating impurities such as ash and asphaltic matter.

These conditions are met in a wide variety of apparatus. Possibly the simplest sulfur burner consists merely of a large brick chamber. A cast-iron pan about 5 inches deep, into which sulfur may be charged, is set in the front of this chamber. The pan should have an area of about 30 square feet per ton of sulfur burned per day. Air for primary combustion is admitted over the pan. This air not only burns sulfur in the pan, but carries from the pan considerable sulfur vapor which burns in the rear of the chamber. Secondary air is admitted under the pan and mixes with the primary products in the rear. By regulating the distribution of air from these two inlets, it is

possible to control the temperature of the molten sulfur, and introduce any desired proportion of secondary air.

The older burners, in which the pan was set on the floor, were not successful because it is not possible to secure complete combustion if all the air is admitted as primary air. As the quantity of air entering over the sulfur is increased, this merely increases the total quantity of sulfur burned and sublimed. At any given temperature, there will be an equilibrium between air and sulfur, in accordance with which the air will carry a certain proportion of sulfur vapor. Increasing the volume of primary air increases the quantity of air which can carry sublimed sulfur. This also increases the rate of combustion, thereby increasing the temperature and consequently the vapor pressure of the sulfur, with correspondingly increased sublimation.

The Glens Falls sulfur burner (Fig. 13) consists of a horizontal steel cylinder with conical ends, revolved on two sets of rolls at a rate of $\frac{1}{2}$ to $\frac{2}{3}$ r.p.m. Sulfur is fed at one end through a wormfeed mechanism, and primary air is admitted at the same place. The heat of combustion melts the sulfur within the cylinder. The rotation of the cylinder distributes this sulfur in a thin film on the inside of the apparatus, and also causes it to shower in drops through the hot gas. The discharge end of the cylinder fits into a combustion chamber, and secondary air to burn sublimed sulfur is introduced here by a sliding

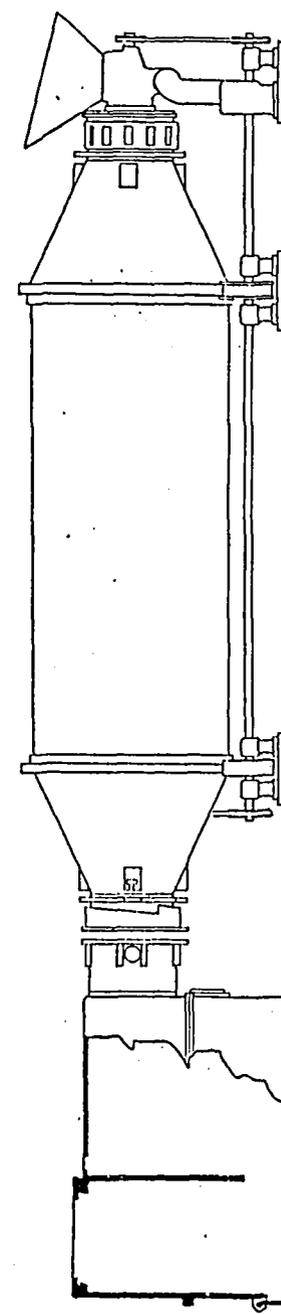


Fig. 13.—Glens Falls sulfur burner.

damper. The agitation of the sulfur prevents the formation on its surface of a film of impurities that might slow down combustion. The cylinders vary from 20 inches by 4 feet to 4 feet by 20 feet; and have a capacity of one ton of sulfur per 24 hours for each 24 cubic feet of cylinder volume.

The most recent tendency in sulfur burners has been to avoid complicated mechanical construction of the burner itself and to put the principal emphasis on subdividing the sulfur to give a large surface for combustion. One type⁽⁶⁾ consists of a vertical steel cylinder, lined with firebrick and divided with a perforated firebrick arch about a third of the way down. Sulfur is melted in a pit heated by steam coils and is raised to a temperature at which most of the water is driven off. Coarse dirt accompanying the sulfur settles at the bottom of the pit. The molten sulfur is pumped to the burner and cascades down over a conical pile of firebrick carried on top of the arch. Below the arch is a second cone onto which residual unburned sulfur falls. The air, which is predried, enters under pressure through flues, one near the sulfur inlet and one at the level of the arch. This burner is reported to give remarkably complete combustion with a minimum of vaporized and unburned sulfur in the gases.

The Zeisberg spray burner⁽¹¹⁾ also operates with premelted sulfur and predried air under pressure. The sulfur is atomized in a specially constructed steam-jacketed jet, and the flame impinges against a baffle wall of firebrick. The hot gases pass over the tubes of a boiler, thus generating steam and cooling the gases. In order to obtain reasonable boiler efficiency, the burner is operated to produce gas of about 14 per cent SO_2 , but this is diluted with additional air after passing through the boiler to concentrations suitable for acid manufacture.

Pyrite Burners.—The type of burner that is used depends upon the size of the pyrites, since coarse lumps and fine material require different types of burners.

Lump pyrite burners are simply brick-lined fire boxes about 6 feet long and 4 or 5 feet wide, with grates constructed of straight square bars. Since the production of uniform gas and the yield of a maximum amount of sulfur dioxide requires careful attention to the fires, the individual furnaces are made small. The heat of combustion of pyrites is low and hence it is essential that radiation losses be minimized. The furnaces are therefore set in bat-

teries, each battery consisting of two rows, back to back, with a flue between. In order to secure uniform and complete combustion, the depth of fire bed must be considerable and the air must be preheated. Preheating of the air is accomplished by maintaining a layer of hot cinders on the grates. About 50 square

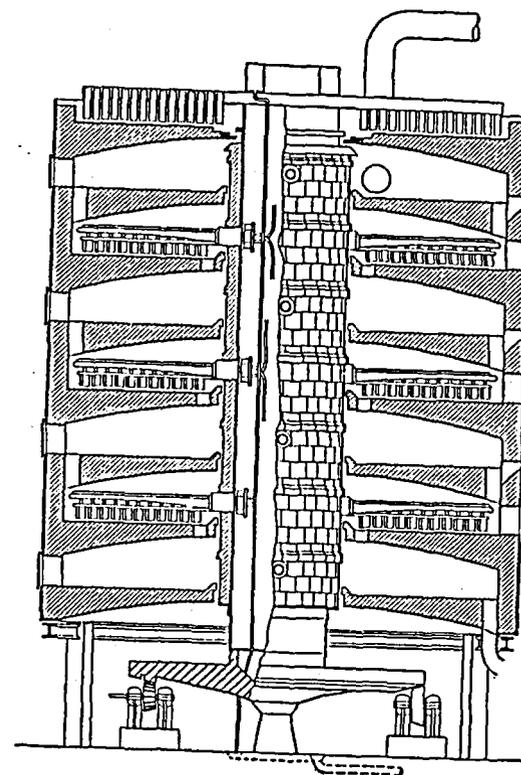


FIG. 14.—Burner for fine pyrites.

feet of grate area is required to burn one ton of 45 per cent sulfur ore per day.

Hearth burners for fine pyrites have been made in a wide variety of designs. The principal features are shown in Fig. 14. The furnace consists of a brick-lined steel shell in the form of a vertical cylinder 10 to 25 feet in diameter, in the axis of which stands a slowly rotating shaft. In the interior of this cylinder are constructed a number of superimposed firebrick hearths. The central shaft carries two or more arms for every hearth.

Rabbles on these arms are set at such an angle that they draw the ore toward a central opening in every alternate hearth, and push it toward an opening near the circumference of the other hearths. The shaft and the rabble arms are cooled, and the different designs differ in the method of cooling, the provisions for making repairs, and similar details. Most of the air for combustion is introduced at the bottom hearth and rises counter-current to the flow of material. The air is preheated by the burned cinders on the lower hearth. Combustion takes place on the intermediate hearths and the descending pyrites are preheated by the hot gases on the upper hearth. If the burner temperature becomes too high, additional air is introduced at intermediate hearths. These furnaces require about 100 square feet of hearth area per ton of ore per day.

In many metallurgical operations where pyritic ores are concentrated, pyrites are available in the form of relatively fine material. One method that has been employed for burning such material is the flash burner.⁽⁷⁾ The fine concentrate, as received, is fed into a ball mill through which primary air for combustion is blown. The purpose of this mill is not to grind the material but to suspend it in the stream of air. This stream of air and fine pyrites is blown into the center of the top of a vertical cylindrical combustion chamber with a hopper bottom. Most of the cinder falls from this hopper onto a conveyer, and secondary air enters through the gap between the hopper and the conveyer. The gas offtakes are near the top, so that the flame travels downward through the center of the chamber and up along the walls.

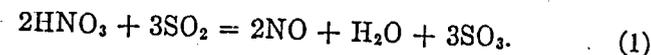
Because of the presence of finely divided iron oxide, which can act as a catalyst for the conversion of sulfur dioxide to SO_3 , it is necessary to cool the gas rapidly to a temperature at which this reaction cannot take place. It therefore passes first through small dust catchers, and then through a steam boiler, which reduces its temperature to about 350°C . It is then washed and scrubbed in the usual way.

In order to prevent too high conversion to SO_3 and too rapid destruction of the brick lining of the combustion chamber, it is necessary that the temperature of the combustion space be kept at about 1000 to 1100°C . The combustion of the pyrites would normally produce a temperature higher than this and, therefore, a part of the cooled burner gas is returned to the ball mill to dilute

the products of combustion and thus control the temperature in the combustion space.

Burner Gas.—Experience has shown that the best results in the chamber plant are obtained when the gas from the sulfur burners contains 8.5 to 9.0 per cent sulfur dioxide. This corresponds to 12.0 to 12.5 per cent free oxygen. In the burning of pyrites, part of the oxygen of the air is combined with the iron. Maintenance of the proper ratio of sulfur dioxide to oxygen, therefore, results in pyrites burners being operated to give a gas of 7.0 to 7.5 per cent sulfur dioxide. In both the above cases, sufficient excess oxygen is left in the burner gas so that the waste gas from the process carries 8.5 to 9.0 per cent oxygen.

Niter Supply.—The former method of replacing losses of oxides of nitrogen was to charge sulfuric acid and sodium nitrate, in approximately equimolecular proportions, into a cast-iron vessel known as a *niter hog*. This was set in the flue carrying the hot gas from the burner to the Glover tower, to supply the heat to carry out the reaction and vaporize the nitric acid. When the nitric acid vapor mixed with the burner gas, it was reduced. The reaction is probably



Since 1926–1927, practically the only method in use in the United States for supplying oxides of nitrogen to the chamber process has been by the oxidation of ammonia^(4,5) (see page 98).

In this process a mixture of ammonia and air is passed over heated platinum gauze, and if the proper conditions are maintained the nitrogen of the ammonia is almost quantitatively oxidized to NO. The apparatus is compact and easily operated. The supply of oxides of nitrogen to the process can be accurately and instantly regulated by turning a single valve; and at present prices of ammonia and saltpeter, it is much cheaper than the older methods.

The apparatus consists of a blower for furnishing air, a catalyst chamber, and a heat interchanger. If liquid ammonia is used, the air is preheated in the heat interchanger, and the ammonia is introduced through a control valve just before the mixture enters the catalyst. The heat of reaction is sufficient to preheat the incoming gases to the reaction temperature. If aqua ammonia is used, the air first passes up a small column down through

which aqua ammonia is passed. The mixture of air and ammonia is then preheated, but to avoid decomposition of the ammonia the heat exchanger must be made of nickel or aluminum.

The losses of oxides of nitrogen in the whole process, calculated as sodium nitrate, amount to about 4 per cent of the total weight of sulfur burned. This holds true for plants operating on sulfur or a good grade of pyrites. Plants operating on metallurgical gases of varying compositions may use as high as 8 or 9 per cent sodium nitrate. The niter loss also varies with the method of plant operation, since forcing the plant to high capacities results in a proportionately increased loss of oxides of nitrogen. With uniform operation at moderate rates the loss may be held down to 2 per cent.

Dust Collectors.—When pyrites are burned, if the fine material carried over with the gases were not removed, it would soon clog the Glover tower. The usual method is to introduce, between the burners and the Glover tower, a chamber whose cross-section is considerably larger than the gas flue. This chamber may be empty and depend merely on a decrease in gas velocity to drop the suspended particles; or it may be provided with baffles. The cross-section should be such as to reduce the gas velocity to about 3 feet per second, and it should be long enough to give the gases a total time in the chamber of 0.5 to 0.75 minute.

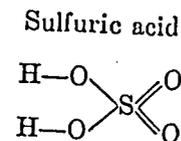
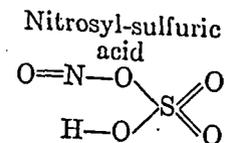
In some plants, especially those operating on smelter gases, the Cottrell system of electrical precipitation is used. This requires cooling and humidification of the gases. It consists in passing the gases through paths of relatively small cross-section, each carrying a central electrode. Between this electrode and the wall of the conduit a high-potential unidirectional electrostatic field is maintained. The solid particles are electrified and attracted to one of the poles. Provision is made for jarring the electrodes at intervals so that the accumulated dust falls into a hopper below.

The Glover Tower.—From a study of Fig. 12 and the description that accompanies it, it will appear that the Glover tower has several functions. Among these may be mentioned:

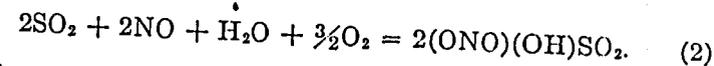
1. Cooling the burner gases.
2. Concentrating chamber acid.
3. Returning to the system oxides of nitrogen that have been recovered in the Gay-Lussac tower.

4. Supplying water vapor to the first chamber.

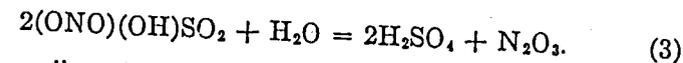
Before proceeding to a more detailed discussion of these it will be necessary to consider some reactions of general importance. The reactions that take place in the chamber process have been the subject of many controversies, but the theory advanced by Lunge⁽³⁾ has had the widest acceptance and has withstood criticism. Nevertheless, it is not complete, and there are many details of the operation of the chamber process that are not yet fully understood. According to Lunge, a very important place is held by a compound called nitrosyl-sulfuric acid, whose relation to sulfuric acid is shown by the following structural formulas:



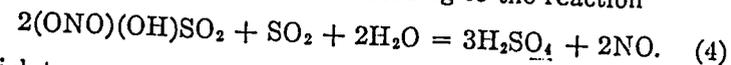
In the presence of sulfur dioxide and some free oxygen, this acid can be formed by the following reaction:



This compound is easily hydrolyzed, liberating sulfuric acid and N_2O_3 according to the reaction



It is also easily reduced by SO_2 according to the reaction



High temperatures not only favor a more rapid rate of reaction, but also give an equilibrium corresponding to more complete decomposition of the nitrosyl-sulfuric acid. It is obvious that both reactions (2) and (4) are favored by high concentrations of sulfur dioxide; reaction (2) taking place where concentrations of NO are high, and reaction (4) where they are low.

It will be apparent, therefore, that the Glover tower is adapted to accomplish the recovery of nitrogen oxides from Gay-Lussac acid by hydrolysis in the upper part of the tower, and by reduction by means of sulfur dioxide in the lower portions of the tower. Gay-Lussac acid is fed into the top of the Glover tower

and in addition there is added the comparatively dilute chamber acid; or should the chamber acid be taken off as a separate product, water is added in its place. Hot burner gases entering the bottom of the tower and carrying a relatively high content of sulfur dioxide are able to decompose, according to reaction (4), any nitrosyl-sulfuric acid that may have reached the bottom of the tower. Thus, the acid issuing from the base of the Glover tower should contain only a trace of oxides of nitrogen. As the burner gas rises through the tower, it carries not only the nitric oxide supplied to the process, but increasing amounts of nitric oxide liberated from Gay-Lussac acid. This makes possible the direct synthesis of nitrosyl-sulfuric acid by reaction (2) at certain intermediate zones in the tower. Because of the high temperature of the gas it is able to concentrate the acid which it meets and, therefore, as it ascends, it also carries increasing concentrations of water vapor. This, combined with the dilution caused by chamber acid or water at the top, gives a zone in the upper part of the tower where nitrosyl-sulfuric acid is decomposed by hydrolysis. Thus, it will be seen that in addition to the functions previously mentioned, the Glover tower has another and very important one; namely, the synthesis of sulfuric acid. The acid formed in the tower may be as much as 20 per cent of the total output of the system.

The construction of the Glover tower varies considerably, but present practice favors a tower built of acid-proof brick, with or without a sheet-lead sheath, and resting in a lead pan (Fig. 15). On this lead pan is laid an acid-proof masonry floor, which supports the walls of the tower and also arches, which in turn support packing material with which the tower is nearly filled. A special distribution device at the top of the tower insures uniform wetting of the packing with the acid. Thus the liquid is filmed out over the packing material in the tower while the gas is forced to pass up through this packing, and the two phases are brought into intimate countercurrent contact.

All the reactions taking place in the Glover tower involve the interaction of a liquid and a gas. At the high temperatures of the Glover tower all these reactions are very rapid and a relatively short time of contact is sufficient. Consequently, a rather coarse packing with relatively large free spaces is satisfactory. The packed section should be 30 to 40 feet high. Ordinary practice

calls for a gas velocity (figured at standard conditions) of approximately 0.8 foot per second. These height and velocity figures correspond to a packed volume of 0.07 cubic foot per pound of sulfur burned per day.

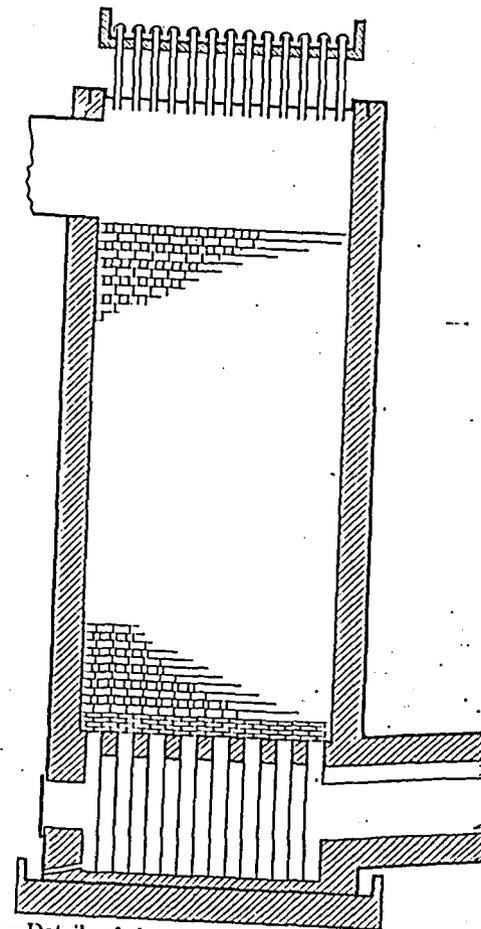


FIG. 15.—Details of chamber-plant construction: Glover tower.

Lead Chambers.—The lead chambers are essentially large vessels that allow space, and therefore time, for the major reactions to take place before the gases leave the system. The gases entering the first chamber from the Glover tower contain water vapor and a relatively high concentration of sulfur dioxide and free oxygen. The oxides of nitrogen at this point are almost

entirely NO, as shown by the fact that the contents of the first chamber are usually without any trace of red oxides.

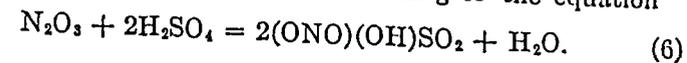
The reactions by which sulfuric acid is made in the chambers result in the evolution of heat, so that the central portions of the chambers are always warmer than the outer portions, which are exposed to the cooling influence of the surrounding air. The chambers are filled with small floating particles of mist that circulate about with the chamber gases, rising in the central portions of the chambers and falling near the sides. These mist particles consist of nitrosyl-sulfuric acid and sulfuric acid of varying dilutions. Since the partial pressure of water vapor within a given chamber is more or less uniform, and since these particles are hotter in the central portion of the chamber, they will, therefore, be more concentrated in the central part of the chamber and more dilute toward the walls. In the central areas sulfur dioxide, nitric oxide, and oxygen can unite to form nitrosyl-sulfuric acid; whereas at the walls, where the temperature is lower, water vapor condenses on the drops, diluting them, hydrolyzing the nitrosyl-sulfuric acid, and liberating oxides of nitrogen. Any N_2O_3 liberated will recombine with great rapidity with sulfur dioxide and water, forming more nitrosyl-sulfuric acid; for the gas in the first chamber is substantially colorless.

Much of the difficulty in assembling a coherent theory of the chamber process centers around the question of which oxides of nitrogen are present and what their various functions may be. The oxides of nitrogen involved in the process are commonly considered to be three in number; NO which is colorless, NO_2 which is reddish, and N_2O_3 which is deep red. At the temperature of the chambers, N_2O_3 cannot exist except in very small concentrations. If it is formed by the hydrolysis of nitrosyl-sulfuric acid it must almost completely dissociate according to the reaction

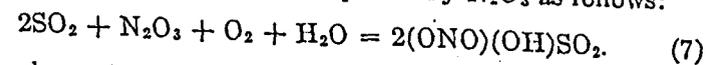


That NO_2 , except such as results from this dissociation, does not enter into reactions in the chambers, is evidenced by the fact that an excess of NO_2 over NO is never found in the chamber gases. Any NO_2 that is present probably reacts not as such, but by combining with NO to form N_2O_3 . Consequently, the assumption that only NO and N_2O_3 or its equivalent are present, gives a satisfactory explanation of the reactions in the chambers.

It has been observed that the contents of the earlier chambers are white or colorless, while the later ones show an increasing reddish color. This indicates the absence of N_2O_3 from the first chamber. This is usually explained by assuming the formation of nitrosyl-sulfuric acid according to the equation



As the gas proceeds through the chambers, its temperature is lowered and at the same time the sulfur dioxide concentration is decreased, the decomposition of nitrosyl-sulfuric acid according to equation (4) decreases, its hydrolysis by water with the formation of N_2O_3 increases, and thus the increasing color is explained. Equation (2) calls for the synthesis of nitrosyl-sulfuric acid by nitric oxide and oxygen. In the presence of lower concentrations of sulfur dioxide and at lower temperatures, the NO in this equation may be replaced by N_2O_3 as follows:



It has been stated above that at temperatures existing in the chambers N_2O_3 exists only in very small concentrations. The residual concentration of N_2O_3 at equilibrium is sufficient for reaction (7), thereby removing N_2O_3 from the gas phase and causing NO and NO_2 to react with the formation of more N_2O_3 .

The reactions that have been discussed result in the removal of water from the chamber gases to form sulfuric acid. The water vapor supplied by the Glover tower is usually sufficient for the first chamber, but in succeeding chambers water must be added as steam or fine spray.

Chamber Construction.—The usual lead chamber is a rectangular vessel of sheet lead supported on a suitable framework. These chambers may be 50 to 150 feet long, 16 to 26 feet high, and 20 to 30 feet wide. There are usually three to six chambers; and they may all be of the same size, but it is more common to make the first chamber longer than the others. For a given method of working, the total capacity in cubic feet of chamber space per pound of sulfur burned is fairly constant.* The older chambers had a wood framework, but modern construction employs steel. Because of the tendency of lead to crawl (deform beyond the elastic limit) it must be fastened securely at frequent intervals. This is usually accomplished by burning tabs of lead

* See p. 58.

to the side walls at intervals not less than 3 feet apart each way, and securely fastening these tabs to the supporting framework (Fig. 16). The top of the chamber is hung in a similar manner.

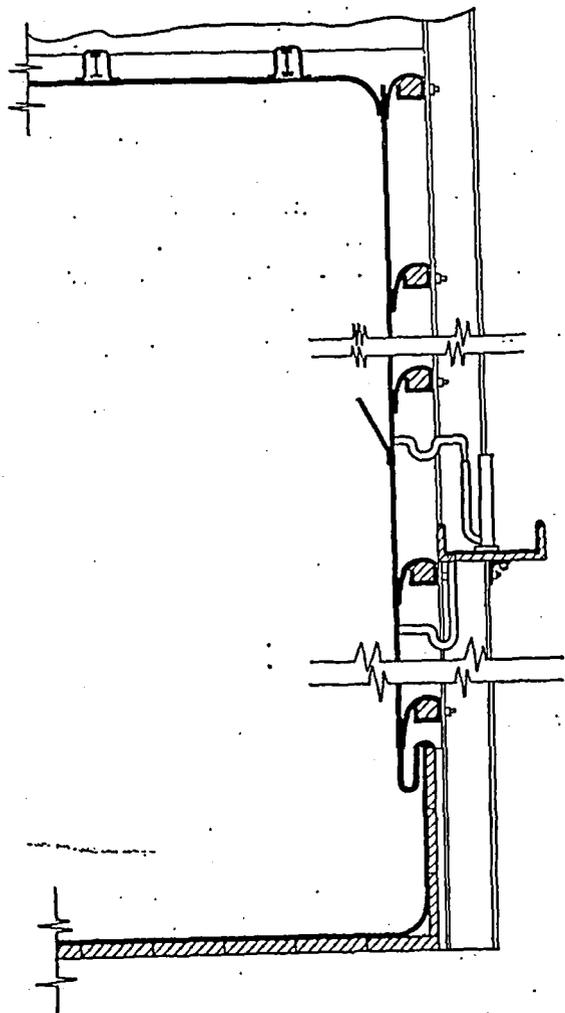


FIG. 16.—Details of chamber-plant construction: chamber construction.

Through the top project spray nozzles for the introduction of steam or, preferably, water mist. The bottom of the chamber is a pan with upturned edges which are burned to the bottoms of the side walls. At intervals along the side walls a gutter is burned on

the inside with a small connection to the outside of the chamber. A portion of the acid condensed on the chamber walls drains into this gutter and drips from a spout outside the chamber. The density of these drips, together with the temperatures of the chambers, furnishes the information by which the process is usually controlled.

Gay-Lussac Tower.—If the chambers are properly operated there will be a very small concentration of sulfur dioxide in the gas leaving the final chamber, and there should have been no loss of oxides of nitrogen up to this point. Since the Gay-Lussac tower is fed at the top with cold 60° acid, conditions are favorable to reaction (6). It is obviously important that the concentration of sulfur dioxide be kept low, otherwise equation (4) would take place with loss of oxides of nitrogen. On the other hand, if the sulfur dioxide be exhausted before the gas leaves the last chamber, nitric acid will form in the last chamber, condensing on the chamber walls and corroding them. Exhausting the sulfur dioxide will also permit the excess oxygen, required for the chamber reactions, to oxidize nitric oxide to nitrogen dioxide in excess of that corresponding to N_2O_3 . The excess nitrogen dioxide will not form nitrosyl-sulfuric acid, and is only slightly soluble in sulfuric acid. The function of the Gay-Lussac tower is relatively simple and is represented in normal working by equation (6). Some oxides of nitrogen are always lost from the top of the Gay-Lussac tower, due partly to the presence of SO_2 [equation (4)], partly to inability to carry equation (6) to completion, and partly to the presence of an excess of NO_2 .

The Gay-Lussac tower is usually about the same in cross-section as the Glover tower, but since the temperature is low and the reactions are less rapid, a longer time and a more intimate contact between gas and liquid are required to bring them even approximately to completion. Therefore, the packing is finer than in the Glover tower so as to expose more surface per unit volume, and the length of this packed space is usually at least twice that of the Glover tower. . . Since it is inconvenient to build a single tower so high, there are usually two Gay-Lussac towers operating in series. The total length of the packed section in the Gay-Lussac tower is about 70 feet (two towers of 35 feet each). With usual packings, these figures correspond to a time of contact of liquid and gas of about 50 seconds* and a lineal

* For packing having 50 % free volume.

velocity of gas through the empty tower of about 0.6 foot per second, at standard conditions.

The volume of 60° acid pumped over the Gay-Lussac tower is one to three times the volume of acid made in the chambers, the actual quantity being so adjusted that the acid leaving the tower will contain 1 to 2.5 per cent of N_2O_3 by weight. More intensive working of the chambers, which requires a higher concentration of oxides of nitrogen in the chambers, will therefore require more acid for the Gay-Lussac.

Movement of Gases.—It is necessary to provide some means for moving the gases through the chambers and towers and creating a draft for the burners. This may be done by interposing a fan at some place in the system, as between the burners and the Glover tower, or on the exhaust gases from the Gay-Lussac tower. In place of a fan, the gases from the Gay-Lussac tower may be conducted into the boiler stack. This has the advantage of eliminating the maintenance of fans.

Transportation of Acid.—Since very large quantities of acid must be handled in a chamber plant of even moderate size, the apparatus for moving this acid is of importance. One very simple device, formerly used almost entirely and still extensively used, is the acid egg or blow-case. Most modern plants handle acid entirely with centrifugal pumps. These pumps are available in a number of designs, either in hard lead or Duriron, and have proven entirely satisfactory. Sixty-degree acid or stronger, free from dissolved oxides of nitrogen, can be handled in specially designed cast-iron centrifugal pumps.

Coolers.—The hot 60°Bé. acid from the base of the Glover tower must be cooled. The coolers consist of a series of water-jacketed lead tubs, filled with lead cooling coils. This design of cooler facilitates the removal of sulfur carried from the base of the Glover tower; and as the Glover acid is quickly mixed with partially cooled acid, corrosion of the lead is minimized.

Special Systems.⁽⁹⁾—In the previous discussion, it has been developed that acid formation in the chamber process depends on the mixing of gases and spray in the chambers, and on the dissipation of the heat liberated by the reaction. In the ordinary lead chambers, mixing takes place chiefly by diffusion and convection, and the heat of reaction is dissipated by radiation from the walls to the surrounding air. Such chambers use from 6 to 12

cubic feet of chamber space per pound of sulfur burned per 24 hours. It is obvious that the rate of reaction could be increased and the amount of chamber space decreased if devices were added for mixing the gases, for removing heat, or for bringing the gas and liquid phases more thoroughly into contact with each other.

A number of systems have been devised for accomplishing some of these aims. None of them has been adopted to the exclusion of the standard process, and some of them have found very little recognition. The only one that has met with great favor in the United States is the Mills-Packard system. It employs lead chambers in the form of truncated cones, of 7,000 to 18,000 cubic feet each. The particular feature of the process is that a film of water is allowed to trickle down the outer surface of these cones to remove the heat of reaction. This results in rapid cooling and condensation on the inner surface of the chambers, so that Mills-Packard systems operate with 3 to 5 cubic feet of chamber space per pound of sulfur burned and a niter rate of about 3 per cent.

Purification of Sulfuric Acid.—When acid of high quality is desired, it is usually sufficient to specify that it be made from brimstone. If acid of the highest purity is needed, it can be obtained by specifying that it must be made by the contact process. The very rigorous purification that the gas receives in the contact process means that contact acid will always be appreciably purer than chamber acid. In some cases where chamber acid is made from pyrites or blende, it may have to be treated to remove arsenic.

This is best carried out by passing hydrogen sulfide through acid of 50 to 53°Bé. It may be done in towers, or in special apparatus in which rapidly rotating paddles subdivide the acid and bring it into contact with the gas. The sulfide precipitate is then removed by sand or coke filters. There are uses for impure acid, and in most plants in the United States, purification is not necessary.

CONCENTRATION OF SULFURIC ACID

Usually, chamber plants are so located that they dispose of most of their acid at 53 or 60°Bé. The demand for acid of 66° or stronger is usually met with contact acid. There are cases, however, where it is desirable to concentrate either chamber acid

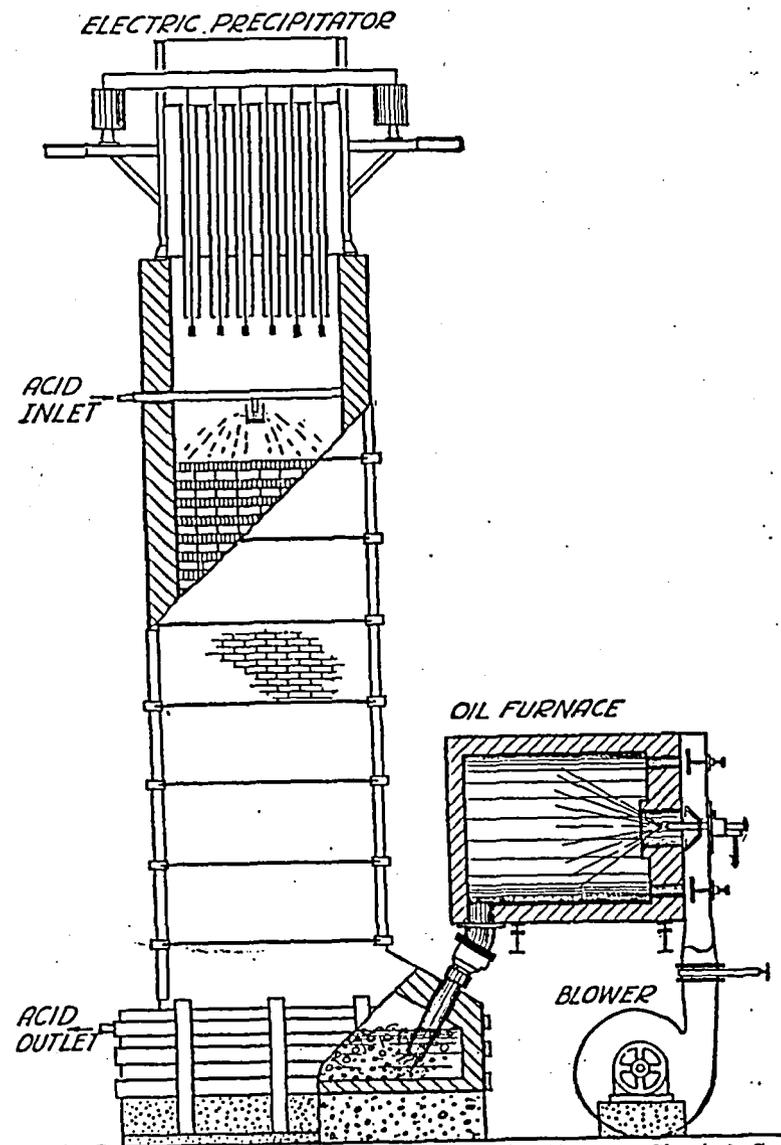


FIG. 17.—Chemico concentrator for sulfuric acid. (Courtesy Chemical Construction Company.)

or Glover tower acid to 66°. This is usually done by methods in which hot gases are brought into direct contact with the acid; and may be illustrated by the Chemico concentrator (Fig. 17).⁽⁹⁾ Other variants of this system differ only in structural details.

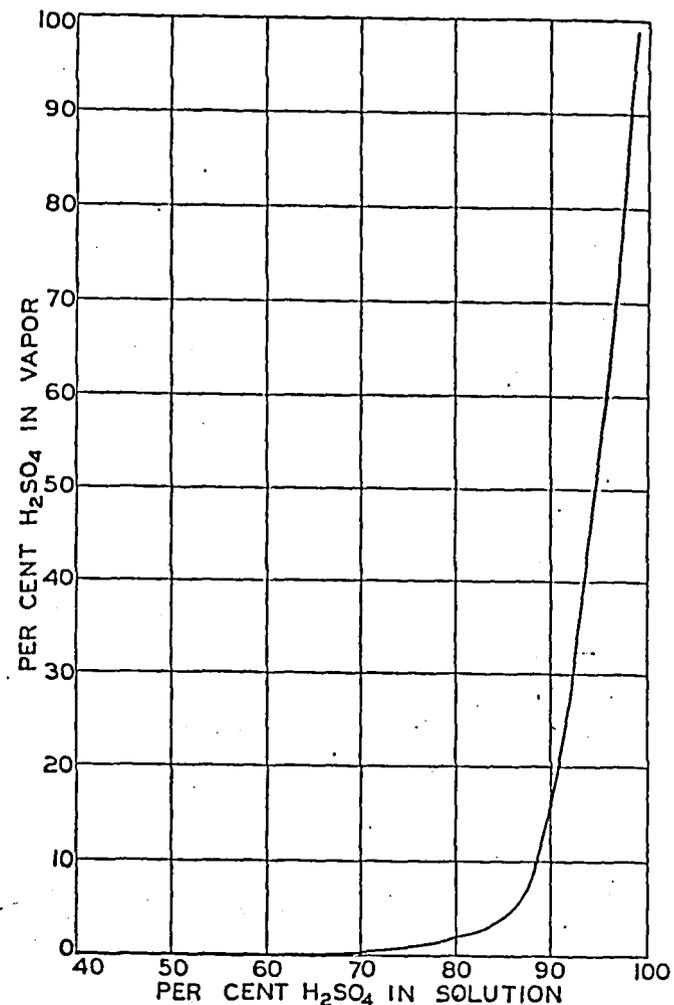


FIG. 18.—Concentration of sulfuric acid in vapor at the boiling point.

The acid to be concentrated is fed at the top of the tower. The tower is filled with quartz or stoneware packing, and delivers the acid at the bottom to a pan. This pan is lined with acid-

proof masonry, and is heated by the products of combustion from a gas or oil burner. At the back of this pan the concentrated acid overflows to coolers and a storage tank. The gas leaving the top of the tower contains considerable sulfuric-acid mist, and is therefore conducted through a Cottrell electrical precipitator. The acid collected by the precipitator drains back into the tower.

Tower concentrators are similar in operation to a Glover tower, and have a correspondingly large capacity with low cost of maintenance. When fired with gas or oil, the purity of the acid is not decreased in passing through the concentrator, and the product may be water-white if the tower is fed with chamber acid.

Figure 18⁽¹⁰⁾ shows the equilibrium concentration of sulfuric acid in the vapor phase, corresponding to various concentrations in the liquid phase, at the boiling point at one atmosphere. It will be apparent that the vapor from boiling 66°Bé. acid would contain about 30 per cent sulfuric acid, whereas the vapors from 50°Bé. acid will be acid-free. Inert flue gas in the tower system lowers the partial pressure of the acid vapor and therefore concentration takes place at much lower temperatures. This results in a lower concentration of acid in the gas phase than that called for by Fig. 18. Tower concentrators possess a further advantage in that they function in much the same manner as a rectifying column. Acid vaporized in the lower part of the tower is largely absorbed in the cooler and more dilute acid descending in the upper portions of the tower.

Sludge Acid Concentration.—In the petroleum industry considerable quantities of *sludge acid* are produced. This is acid that has been used to treat various petroleum fractions and contains organic material dissolved in the form of sulfonates or suspended in the form of emulsions. Sufficient quantities of this material are produced so that it must be reconcentrated. Various other organic industries may produce waste acid contaminated with organic matter. Such materials are usually recovered, not so much because of the value of the acid as to eliminate waste-disposal problems.

One common form of concentrator is shown in Fig. 19. It consists of a horizontal, cylindrical steel shell lined with acid-proof brick. This is divided into a furnace chamber at one end and two concentrating chambers at the other end. The furnace is

fired with oil or gas under sufficient pressure to cause the hot products of combustion to bubble directly through the material to be concentrated in the other two chambers. The weak acid is fed into one of the concentrating chambers and then flows by gravity into the other. The reason for this separation is that the weak acid very often foams, possibly due to a reduction of the acid to sulfur dioxide by the organic matter which may reduce the yield to 70 to 75 per cent of the acid entering.

The gases pass from the drum into which the dilute acid is fed, to a mist separator. This consists of a short layer of packing

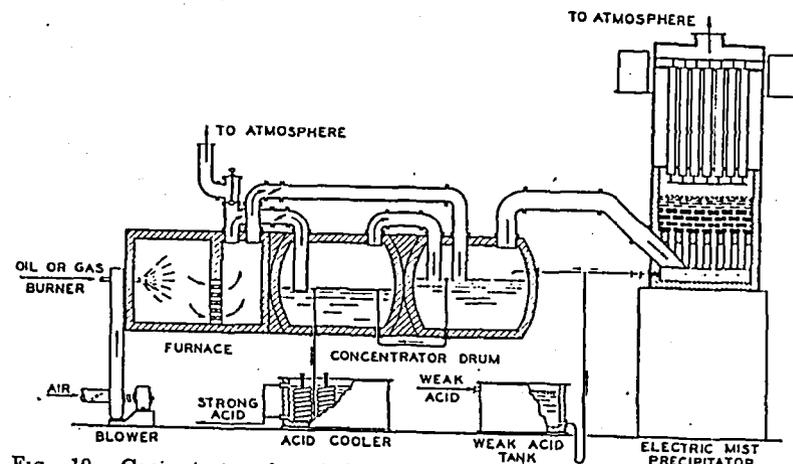


Fig. 19.—Concentrator for sludge acid. (Courtesy Chemical Construction Company.)

supported on acid-proof brick arches and followed by a Cottrell electrostatic separator.

Various other types of sludge acid concentrators are in use, in at least one of which the acid is concentrated at a high vacuum by means of high-pressure steam in lead coils or in tubes of high-silicon iron. Originally, this concentrator was run with a vacuum of about 28 inches. This took steam up to 250 pounds and did not result in the highest concentration of acid. The particular difficulty, however, was that under a vacuum of 28 inches the temperature of the acid was high enough to cause a reaction between the organic matter and the acid, resulting in foaming and loss of acid by reduction. Later, these concentrators were run under very high vacuum (5 to 10 millimeters). This gives, first,

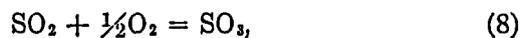
a low enough boiling point so that 120-pound steam can be used and, second, a low enough boiling point so that there is no reduction of the acid by organic matter. Yields are of the order of 95 per cent of the incoming acid.

Sometimes special steps are taken to break emulsions or to coagulate the organic matter, thus leaving an acid containing less organic matter to go to the concentrators. The organic material is either discarded, or, if large quantities are available, it may be treated by a process in which all the acid it contains is reduced to sulfur dioxide and this is then sent to a contact plant. The carbon dioxide in this gas is objectionable in the contact plant only because it lowers slightly the concentrations of sulfur dioxide and oxygen.

THE CONTACT PROCESS

Many industries, especially those organic industries that involve nitrations, require high concentrations of sulfuric acid. While 66°Bé. acid may be obtained by the concentration of acid from the chamber process, sulfuric acid of 100 per cent or stronger cannot be made in this way. Such strong acids are made by absorbing sulfur trioxide in 66° acid. Sulfur trioxide was first obtained by the dry distillation of ferric sulfate or shale containing alum or other heavy metal sulfates. Difficulties in the production of large amounts of sulfur trioxide by these methods created a demand for a method for making it directly from sulfur or pyrites. The successful development of the oxidation of sulfur dioxide directly to sulfur trioxide, which was accomplished between 1890 and 1900, laid the foundations for what is now known as the contact process for the manufacture of sulfuric acid. The design of a successful contact acid plant was accomplished, however, only after a satisfactory understanding of the equilibrium between sulfur dioxide and sulfur trioxide.

Theory of the Contact Process.—From a consideration of the equation



it is obvious that at equilibrium the relative concentrations of the reacting substances at any particular temperature, are defined by

$$K = \frac{P_{\text{SO}_3}}{P_{\text{SO}_2} \sqrt{P_{\text{O}_2}}}, \quad (9)$$

where these pressures refer to the partial pressures of the various gases, expressed in atmospheres, after equilibrium is obtained.⁽¹¹⁾

This reaction is exothermic and consequently an application of Le Chatelier's theorem shows that the position of the equilibrium must shift with increasing temperature in such a way as to call for lower conversions of sulfur dioxide to trioxide. If the heat of the reaction at any one temperature and the specific heats of the reacting substances are known, it is possible to calculate the variation of K with temperature fairly accurately. With the best values for the constants it is found that

$$\log_{10} K = \frac{8,775}{t} - 4.46 \quad (10)$$

where t is temperature in degrees Rankine. Table X presents a series of values of K calculated from this equation and corresponding experimental values obtained by Knietsch and Bodlander.

TABLE X.—EFFECT OF TEMPERATURE ON EQUILIBRIUM CONSTANT IN THE CONVERSION OF SO_2 TO SO_3

$t^\circ \text{C.}$	$t^\circ \text{F.}$	t° Rankine	K calculated	K observed	Observers
450	842	1,302	191.4	187.7	Knietsch
500	932	1,392	70.0	72.3	Knietsch
515	959	1,419	53.2	65.4	Bodlander
553	1,027	1,487	27.5	24.1	Bodlander
600	1,112	1,572	13.3	14.9	Knietsch
610	1,130	1,590	11.5	10.5	Bodlander
700	1,292	1,752	3.55	4.84	Knietsch
800	1,472	1,932	1.21	1.81	Knietsch
900	1,652	2,112	0.20	0.57	Knietsch

If 100 mols of burner gas containing a mols of SO_2 , b mols of O_2 , and c mols of SO_3 are brought into equilibrium at any given temperature, x mols of SO_3 will be formed. This will cause the disappearance of $0.5x$ mol of O_2 and x mols of SO_2 . If the total pressure is 1 atmosphere, the partial pressure of SO_3 in the resulting gas will then be

$$\frac{x + c}{100 - 0.5x}$$

because there has been a net contraction in volume of $0.5x$. In

the same way the partial pressure of SO_2 in the resulting gases will be $\frac{a-x}{100-0.5x}$, and of O_2 , $\frac{b-0.5x}{100-0.5x}$.

Substituting these values in the equation for K above we have the following:

$$K = \frac{x+c}{(a-x)\left(\frac{b-0.5x}{100-0.5x}\right)^{3/2}} \quad (11)$$

For a particular value of K the corresponding value of x is most simply found by the method of trial and error. Several values may be assumed for x and substituted in the right-hand member of this equation. That value of x which gives the desired value for K is the solution. Graphic interpolation may be used to shorten the work.

Rate of Reaction.—The above discussion is based on conditions that would obtain if equilibrium were reached, and says nothing about the time necessary to reach that equilibrium. Numerical data for these rates are still too fragmentary to include here,⁽¹²⁾ but all reactions increase in velocity considerably with moderate increases in temperature. In this particular case, even at temperatures above 1100°F ., the rate of reaction is very slow. Although at higher temperatures the reaction may be more rapid, equilibrium, if reached, is at low concentrations of sulfur trioxide. By the use of a catalyst, however, the velocity of the reaction can be increased, so that at low temperatures where favorable equilibrium conditions exist, practical operation is possible.

Many substances catalyze this reaction more or less. In burning sulfur, practically no catalyst is present and negligible amounts of sulfur trioxide are formed. In burning pyrites, the Fe_2O_3 acts as a catalyst to a certain extent and small amounts of sulfur trioxide appear in the burner gas. The best catalysts are porous masses containing either finely divided platinum or compounds of vanadium. With either of these, equilibrium can be substantially reached in a few seconds at temperatures from 750 to 850°F .. Temperatures of this order correspond to an equilibrium so favorable that in actual practice conversions of 98 per cent or better are possible.

Sulfur Contact Plant.—The essential steps in a contact process plant using sulfur are (1) burning sulfur, (2) purification of the gas, (3) passing the gas over the catalyst, and (4) absorption in

sulfuric acid of the sulfur trioxide so formed. When sulfur is the raw material, the gas is sufficiently pure so that removal of water vapor and a simple filtration is all that is necessary. The filter is usually merely a layer of the same inert material that is used to carry the catalyst.

Figure 20 is a flow sheet of a somewhat idealized contact process plant burning sulfur. In actual practice no two plants are exactly alike, and there may be no plant that contains exactly the equipment shown in Fig. 20. Sulfur is melted and held at such a temperature that solid impurities settle and water is vaporized. This melted sulfur is then pumped to a sulfur burner which, however, must be supplied with dry air. This air is dried with strong sulfuric acid in a drying tower, and the blower which carries the pressure on the system is usually between the drying tower and the burners.

In Fig. 20 the gas is cooled and filtered before going to the catalyst chambers. These coolers are similar to those described on page 69. In more recent plants operating on sulfur, the sulfur burner may be followed by a waste-heat steam boiler instead of a cooler.

The conversion is carried out in two stages and there are usually two heat interchangers. Cool gas from the filter passes through both heat interchangers in series and then to the first converter at about 400°C . This converter operates at a higher average temperature, contains a relatively thin catalyst bed, and accomplishes most of the conversion. During this conversion heat is liberated, and the gas issues from the first converter at a temperature slightly under 600°C . It goes through one of the heat interchangers to give up some of its heat to the incoming gas stream, and then to the second converter at about the same temperature as at the entrance to the first converter. This converter operates at a lower average temperature, has a much deeper catalyst bed, and accomplishes the final conversion. From the second converter the gas, at about 460°C ., goes through the second heat interchanger and finally to a cooler where it is brought down to a temperature of about 100°C . In starting up a cold plant, a direct-fired preheater may be interposed between the filters and the heat interchangers to start the operation, but this is cut out of the process as soon as the cycle comes up to temperature.

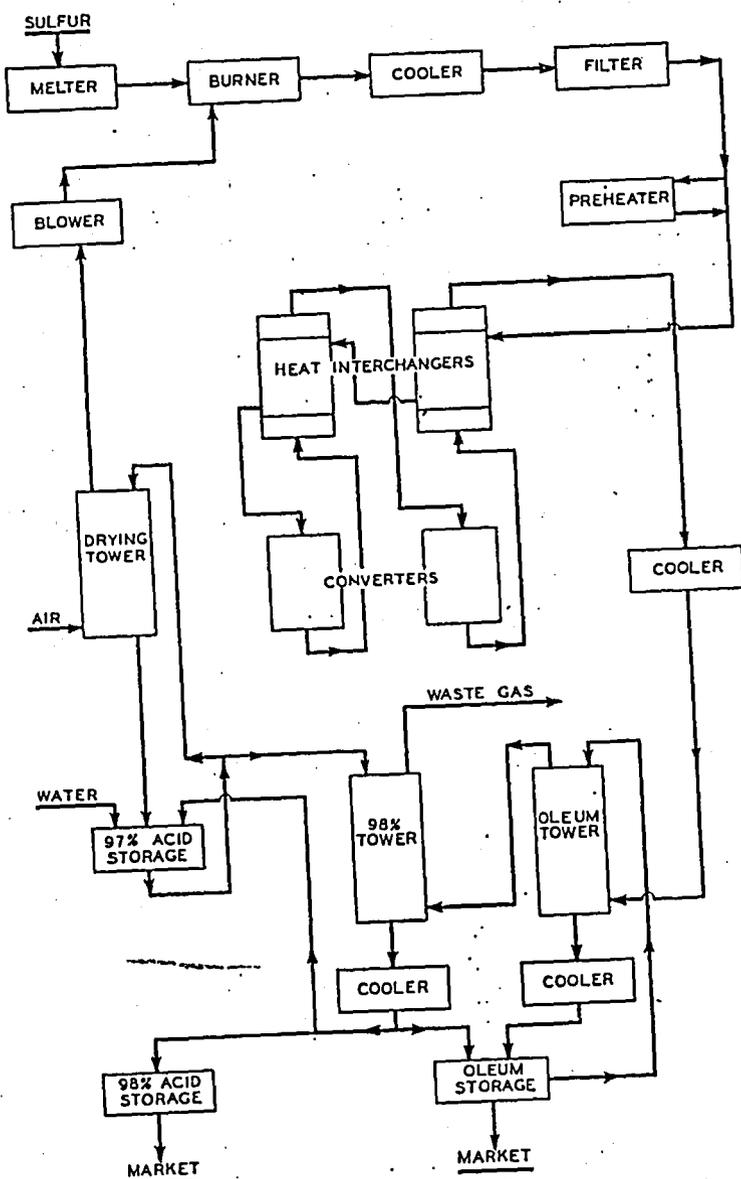


Fig. 20.—Flow sheet of contact process.

The gas, which now contains about 95 per cent of its sulfur as SO_2 , is absorbed in oleum and the feed of oleum to the tower is so regulated that a rise of not over 0.5 to 1.0 per cent in acid strength occurs in passing through the tower. All the SO_2 cannot be absorbed in such strong acid and, therefore, the gas goes next to a tower fed with about 97 per cent acid. The acid fed to this tower is so regulated that the acid strength increases about 1 per cent in passing through the tower. The product from this tower is cooled and part of it may be sold as such, part of it goes to oleum storage to be fortified in the oleum tower, and part of it is fed to the storage tank that supplies acid to the air-drying tower. This last storage tank may or may not have water added according to the amount of moisture present in the air.

In those plants where the gas is not cooled after the burner but passes through a waste-heat boiler, the boiler is operated so that the exit gas is at a proper temperature to be sent directly to the first converter. The heat-interchanger system then disappears and is replaced by a simple cooler, which cools the gas between the two stages of conversion. The preheater also disappears, and the system is brought up to operating temperature by firing oil or gas in the sulfur burner.

Pyrites Contact Plants.—Sulfur is preferred to pyrites as a raw material for the contact process because it gives a purer burner-gas. Pyrites introduce into the gas dust, arsenic and other metallic oxides, and sometimes halogens. Consequently, the purification of gas from pyrites burners is always more complicated than a purification of sulfur burner gas. Where an elaborate purification system is to be employed, as in the treatment of gas from pyrites burners, the burner gas must be cooled to a rather low temperature before the purification system. This is done by passing the gas through unlined cast iron or steel pipe, usually arranged in either horizontal or vertical S-bends. This is usually designed to cool the gas to about 275°C ., at which point a hot Cottrell precipitator may be introduced. Beyond this the gas is usually cooled in lead, and these lead pipes may either be sprayed with water or partially sprayed and partially submerged in water.

No standard flow sheet can be drawn for the purification of pyrites gas because the methods employed are quite varied. They all employ, however, cooling, separating the dust (either in dust chambers or in Cottrell dust collectors), scrubbing with

sulfuric acid, and filtration. If halogens are to be removed, the scrubbing acid is usually under 55 per cent.

Although the scrubbing system gives nearly complete purification, it is necessary that the gas be absolutely free from suspended mist or solid particles. The usual way of removing these is by filtration. Various styles of filters have been used, but the most common one is a rectangular box of relatively large cross-section, lead lined, and filled with coke which has been carefully screened and washed. In a plant that makes 30 tons of acid per day the filter may be 30 to 40 feet wide, 50 to 60 feet long, and 15 feet deep. It should have a sloping bottom from which the acid which is collected may be drained. The coke should be graduated in size and may range from $\frac{1}{2}$ -inch lumps at the bottom to pieces as small as $\frac{1}{4}$ inch or even 10 mesh at the top. Small filter boxes packed with sawdust and asbestos fiber or mineral wool have also been used successfully.

The gas leaving the filter must be thoroughly dry. Unless strong acid was used in the scrubbing system, the final drying follows the filters and is usually done in a cast-iron tower, packed with quartz or stoneware shapes which are sprayed with 97 to 98 per cent acid. From here on the flowsheet of a pyrites plant is the same as Fig. 20.

Heat-transfer System.—After purification the gas is heated to the reaction temperature either by a direct-fired preheater or by heat interchangers. Since the gas is dry, these and subsequent units in the system may be made of steel. Cast iron is less suitable, as the graphite in it is acted on by hot sulfur trioxide. The heat interchangers are ordinary tubular heaters with steel shells and boiler tubes. The gas to be heated usually passes around the tubes. Baffles are placed inside the heater to prevent short circuiting, lengthen the gas path, and increase the rate of heat transfer. The gas which is supplying the heat passes inside the tubes and generally goes through all the tubes in parallel. The direct-fired preheater consists of a large number of boiler tubes connected in series and arranged in the flue of an oil or coke fire.

Catalysts.—The most vital part of a contact plant, and the one about which most discussions have centered, is the type of contact mass used. Originally this was always finely divided platinum and the processes were classified according to methods of

preparation of the catalyst or the construction of the catalyst chamber. At the present time in the United States the only two processes generally recognized are the platinum contact process and the vanadium contact process. There may be considerable differences in flow sheets and equipment between individual plants of each type, but none of these is of general significance.

Platinum contact masses usually consist of finely divided platinum suspended on asbestos mats or on granular silica gel. The amount of platinum used in modern plants is 4 to 6 Troy ounces of metallic platinum per ton of 100 per cent acid made per 24 hours. Although the first cost of the platinum seems high, this is largely offset by the fact that 90 per cent of the platinum can be recovered when the mass is discarded. The platinum contact mass can operate with higher gas concentrations, gives slightly higher conversions, and is possibly more flexible in operation than the vanadium mass.

There are several vanadium contact masses, covered by closely-held patents. The contact mass is sold by the holders of these patents in the form of porous granular material. About 20 pounds of the mass are used per ton of 100 per cent acid made per 24 hours. Although the actual cost of the vanadium compound and the preparation of the mass is a fraction of the first cost of the platinum, royalty charges at present make the equivalent first cost of the vanadium mass higher than that of the platinum mass.

The greater superiority of the vanadium contact mass is its freedom from *poisoning*. The activity of many catalysts is decreased, if not totally destroyed, by the presence of traces of materials called poisons. The platinum contact mass (at least, that on asbestos) is particularly susceptible to such poisons, the most serious of which are arsenic and fluorine. As a consequence of this, the gas for a platinum system must be very carefully purified, since 1 or 2 parts per million of arsenic in the gas will quickly destroy the activity of the catalyst. If the platinum has become poisoned, the catalyst mass must be removed and reworked. The apparent major advantage of the vanadium catalyst is that it is not subject to poisoning. However, the specifications for contact acid are such that the gas must be purified to an extent that neither catalyst would suffer from poisoning. Both types of catalyst are rendered inactive by dust.

Therefore the gas must be carefully filtered in either case. If dust gets into the catalyst mass, the mass must be removed and screened.

The balance of advantages and disadvantages of the platinum and the vanadium masses is at present a controversial subject.^(1,13) Advocates of the vanadium mass claim that its long life offsets its slightly higher first cost. Advocates of the platinum mass insist that with a properly operated plant the life of the platinum is long enough to make the net cost per ton of acid less than with the vanadium catalyst. They also point out that, whereas the vanadium catalyst works best on gases containing 7 to 8 per cent SO_2 , the platinum catalyst operates satisfactorily on gas containing up to 10 per cent SO_2 , thereby reducing the size of the equipment and the cost of the plant. Both types of catalyst are in use in a considerable number of plants in this country, with no indication of a general preference for either type.

Converters.—The converter, or chamber in which the catalyst mass is contained, is simply a cylindrical sheet steel shell, usually with a cone bottom. If the catalyst is platinum on asbestos, the shell contains a number of impregnated asbestos mats, 10 to 13 in a unit, supported by wire netting and held in a steel frame. If the catalyst is a vanadium mass, it is carried on wire screen or perforated metal in somewhat thicker layers.

In the case of a plant in which the sulfur burner is followed by a waste heat boiler so regulated that the gas may be fed to the converter at the proper temperature, the gas filter and the two stages of conversion may be combined in one shell. In this case the gas will enter the bottom of the converter, first through the filter, then through the first catalyst bed, out to a cooler, and then back to the second catalyst bed.

Another method of controlling the temperature of the reaction is to embed a series of vertical tubes in the catalyst bed. Through these tubes air is blown; and the amount of this air is so controlled that the average temperature of the catalyst bed is kept at the desired point. In one type of apparatus these tubes may serve as heat interchangers.

Absorption Systems.—The oleum absorption towers are usually constructed of a sheet steel shell, lined with removable sections of cast iron or with acid-proof brick, and packed with quartz or stoneware shapes. The 98 per cent absorption towers are

usually cast-iron towers similarly packed. The acid coolers both for oleum and for 98 per cent acid are made of cast-iron pipe, which carries the acid in the annular space between it and a smaller cast-iron pipe supplied with cooling water.

The absorption towers may be fed with acid of any strength over 97 per cent. If oleum is to be made, the gas will first pass through a tower over which oleum is recirculated. The concentration of the acid fed to the tower is maintained at 0.5 to 1.0 per cent less than the desired exit concentration. Such strong acids exert an appreciable vapor pressure of sulfur trioxide and, therefore, the absorption in such a tower will be incomplete. In order to insure recovery of the final traces of sulfur trioxide, a counter-current system must be used, and the absorption completed in a tower fed with acid of 97 to 99 per cent so that the residual vapor pressure of sulfur trioxide in the absorbing liquid will be negligible.

Acids more dilute than 97 per cent cannot be used because they exert an appreciable, though low, vapor pressure of water. In the presence of free sulfur trioxide even minute concentrations of water vapor condense to form a mist of sulfuric acid which is very difficult to recover. If sulfur trioxide gas is to be absorbed, there is an appreciable difference in vapor pressure between the gas and liquid phase which causes it to diffuse to the surface of the absorbing liquid. If, on the other hand, instead of gaseous sulfur trioxide, finely divided liquid sulfuric acid is to be recovered, there is no such potential difference tending to drive the particles to the surface of the absorbing liquid. The only way these particles may be removed is by causing them to settle or to impinge on a surface, but both of these are difficult in practice and mist formation must be avoided.

The absorption of sulfur trioxide is strongly exothermic. A large rise in temperature of the absorbing acid in any of the towers is undesirable; for in the oleum towers this means an increase in the vapor pressure of sulfur trioxide with a consequent decrease of capacity, and in the final towers it means an increase in the vapor pressure of water with a consequent tendency to mist formation. Coolers are therefore provided in the acid-circulating system of all towers.

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Problems

- What is the composition of the gas obtained by burning pure FeS₂ with 50 per cent excess air, assuming that all the iron goes to Fe₂O₃?
- A Glens Falls sulfur burner is operated on atmospheric air containing some moisture. The atmospheric pressure is 753 millimeters of Hg and the partial pressure of the water vapor is 13 millimeters of Hg. The gas leaving the primary chamber contains only N₂, SO₂, S₄, and water vapor. The total pressure of this gas is 753 millimeters and the partial pressure of S₄ is 76 millimeters.
How much secondary air, expressed as mols per mol of primary air, must be added in the secondary combustion chamber to burn the sulfur and
 - Yield a gas containing the theoretical requirement for converting all SO₂ to SO₃?
 - Yield a gas containing 10.5 per cent SO₂, dry basis?
 - Yield a gas containing 8 per cent SO₂, dry basis?
- Referring to Problem 2, how many mols of water vapor will be present in the gas leaving the secondary combustion chamber, per mol of SO₂, in each of the three cases stated?
- A sulfuric acid plant makes 100 tons of 60° acid per day. How many pans three by six feet will be needed to burn the sulfur? How many Glens Falls burners, of what size, would do the same work?
- Specify the size of the Glover tower for the plant of Problem 4. If the inlet gas temperature is 1000°F, what will be the actual inlet gas velocity (calculated on the empty tower)?
- Specify the total volume of the chambers and the size of the Gay-Lussac tower, for this plant, if the plant is designed for maximum output per cubic foot of chamber volume.
- How much water must be supplied to the chambers?
- Each of two plants makes 50 tons of 66° acid per day in a tower concentrator. One takes 60° acid from the Glover tower for concentration, the

other finds it necessary to send chamber acid to the concentrator at 53°Bé. What is the saving in water evaporated in the first plant?

9. Three brimstone burner gases, *A* containing 14 per cent SO₂, *B* containing 10.5 per cent SO₂, and *C* containing 8 per cent SO₂, balance in each case O₂ and N₂, are available. Calculate for each gas:

- Concentration of SO₂ at equilibrium at 450°C. and 1 atmosphere.
- The per cent conversion of SO₂ to SO₃ at equilibrium at 450°C. and 1 atmosphere.

10. A contact sulfuric acid plant in the tropics wishes to manufacture acid as strong as possible. The humidity is such that the partial pressure of water vapor in the air is 38 millimeters of Hg. This water is removed by scrubbing with strong acid; the dilute acid resulting must be included in the product (it is all used for dilution in the absorption system, and furnishes all of the water in the product). The burner gas contains 6 per cent SO₂ (dry basis). Assume 98 per cent conversion of SO₂ to SO₃, and 100 per cent conversion SO₂ to acid. Total pressure equals 760 mm.

- What is the strength of the product?
- What is the minimum percentage of SO₂ in the gas that will permit manufacture of 105 per cent equivalent H₂SO₄?

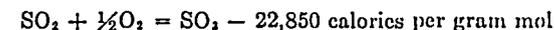
11. Predict the increase in efficiency which could be expected if the operating pressure of a contact sulfuric acid plant were increased from 1 to 8 atmospheres (absolute pressure). The burner gas contains 8 per cent SO₂, and the converters operate at an outlet temperature of 450°C. Assume equilibrium in exit gases.

12. A contact plant is to produce 10 tons of 20 per cent oleum and 40 tons of 98 per cent acid per day. The 98 per cent tower is fed with 97 per cent acid obtained by diluting part of its output. The oleum tower is fed with 19 per cent oleum obtained by diluting part of its output with 98 per cent acid obtained from the 98 per cent tower.

Calculate: (on a per day basis)

- Tons of 98 per cent acid going to oleum tower system.
- Tons of 19 per cent oleum entering oleum tower.
- Tons of 97 per cent acid entering 98 per cent tower.

13. A contact sulfuric acid converter uses the heat of reaction in the first stage for preheating the incoming gas. The heat of reaction (liberated) is



Sufficient conversion is obtained to preheat the gas from 400 to 460°C. The gas from the brimstone burner contains 8 per cent SO₂. If all of the heat liberated goes into pre-heat (i.e., none is lost in radiation, and there is no change in temperature of the converted gas), what fraction of the SO₂ present is converted in this stage of the converter?

Specific heats (mean, between 400 and 500°C.)

Air: 0.25 B.t.u. per pound per degree Fahrenheit.
 SO₂: 0.19 B.t.u. per pound per degree Fahrenheit.

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Second Edition

BY
W. L. BADGER

Professor of Chemical Engineering, University of Michigan

AND

E. M. BAKER

Assistant Professor of Chemical Engineering, University of Michigan

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CHAPTER III

SULFURIC ACID

Sulfuric acid is the most important product of the inorganic chemical industries. It enters into so many different processes in large amounts that the sulfuric-acid market may be considered a better barometer of business conditions than even the iron and steel market. This is not only because sulfuric acid has fully as many applications as iron and steel, but also because, since it is rarely stored, its production and consumption respond more quickly to changes in business activities. Sulfuric acid not only represents the condition of manufacturing industries, but because of its use in fertilizer manufacture it is equally significant as a barometer of agricultural conditions. It has even been said that the industrial development of any country can be measured by its consumption of sulfuric acid.

The technology of sulfuric acid is remarkable in that the chamber process has been operated until recent years with practically no significant changes in equipment or method beyond those which were made at the very beginning. In the last few years many modifications have been suggested, and in some cases adopted. In at least one of these, although the reactions are the same as in the standard process, the plant bears no physical resemblance to the classic arrangement. These changes have coincided with, and at least in some degree are to be ascribed to, a more thorough fundamental knowledge of such unit processes as combustion, fluid flow, heat flow, gas absorption, and the mechanism of heterogeneous reactions. While these developments cannot be described in detail in this book, the trend will be apparent from the mention of the recent special modifications of the chamber process. The effect of a better knowledge of fundamentals is also apparent in the general unification of the contact processes.

Production and Distribution.—The distribution of sulfuric acid in the United States in 1927 was as follows:

TABLE IX.—USES OF SULFURIC ACID

	Percentage
Fertilizers.....	27.8
Chemicals.....	20.9
Petroleum refining.....	19.5
Steel pickling and metallurgical.....	20.0
Paints and pigments.....	3.0
Explosives.....	2.6
Textiles.....	2.0
Miscellaneous.....	4.2

The enormous consumption of acid in the fertilizer industry usually results in acid plants and fertilizer plants being in the same locality. In many cases, the acid plant is operated by the fertilizer factory. The fertilizer plant ordinarily uses an acid of 50° B \acute{e} . and is, therefore, supplied directly with this dilute acid. Other industries either need concentrated acid, or need small enough tonnages so that they may purchase concentrated acid and dilute it. Hence, they do not need to be located at producing centers. The manufacture of explosives, and some branches of the chemical industry, use acids of extremely high strength and may operate their own plants to produce these.

Sulfuric acid is ordinarily sold as 50° B \acute{e} . or chamber acid (62.18 per cent H₂SO₄), 60° B \acute{e} . acid (77.67 per cent H₂SO₄), and 66° B \acute{e} . acid, or oil of vitriol (93.19 per cent H₂SO₄). Acids stronger than 66° B \acute{e} . are usually spoken of by their per cent acid concentration, and 100 per cent sulfuric acid is commonly called monohydrate.

Sulfur trioxide dissolves in monohydrate to give fuming acids or oleum. The strength of these may be expressed in various ways. An acid containing 20 pounds of free SO₃ dissolved in 80 pounds of H₂SO₄ might be spoken of as 20 per cent oleum, or as acid containing 85.3 per cent total SO₃. If to 100 pounds of this mixture sufficient water (4.5 pounds) be added to combine with the free SO₃, there will result 104.5 pounds of 100 per cent H₂SO₄. From this point of view such acid would be called 104.5 per cent acid.

In 1925, the production of these different grades in the United States was as follows:

TABLE X.—PRODUCTION OF SULPHURIC ACID BY GRADES

	Equivalent tons of 50° acid	Percentage of total
50° B \acute{e}	2,166,000	30.9
60°.....	1,503,000	21.4
66°.....	967,000	20.6
Oleum and stronger.....	1,161,000	27.1
Total.....	7,012,000	

NOTE: The average strength of the acid in the entry entitled Oleum and stronger acids, is 101.5 per cent.

The total estimated production, expressed as tons of 50° acid, in 1927 was 6,935,000 tons.

RAW MATERIALS

The earliest commercial raw material for the manufacture of sulfuric acid was sulfur from Sicily. Later many plants turned to iron pyrites (FeS₂) as their raw material. This trend increased until at the beginning of the present century the larger proportion of sulfuric acid made in this country was made from pyrites. When cheap sulfur of high purity from American sources became available, more and more plants turned to sulfur; until in 1920 about 80 per cent of the acid made in this country was made from sulfur. At present the margin of cost between the two raw materials is small, and a relatively slight change of prices may turn the balance in favor of pyrites.

Sulfur.—Before 1900, the world's production of sulfur came entirely from deposits in volcanic regions, the most important of which was in Sicily. Sulfur was mined in the form of a porous rock which contained up to 40 per cent free sulfur. The methods employed were crude and usually consisted in piling the ore in heaps, starting a fire at the bottom, and allowing the heat from the combustion of part of the sulfur to melt the rest, which was collected in molds below the heap. The recovery was incomplete and in recent years more economical apparatus has been used. Even so, the yield is small and the cost high. A small amount of sulfur was imported into the United States as late as 1916 but since that time there have been practically no imports.

The producing areas in the United States consist of scattered deposits, each covering a relatively small area, in the Louisiana-Texas coastal plains. Although these deposits were known in 1865 it was not until the development of the Frasch process in 1891 that production was possible. The Frasch process was so successful that in a relatively short time it was producing almost all the sulfur used in this country.

In these Louisiana deposits, sulfur occurs distributed through a limestone rock, which is covered by thick layers of alluvial deposits and quicksand that effectively prevent its recovery by ordinary mining methods. The Frasch Process^(1,2) consists in pumping highly heated water into the rock to melt the sulfur, and then raising the melted sulfur to the surface with an air-jet lift. A 10- or 12-inch hole is drilled to the sulfur-bearing layer and cased to the surface of the rock. Inside this casing are three other pipes, about 6, 3, and 1 inch in diameter respectively. Water superheated to 330 to 350° F. is pumped down through the 3-inch pipe and distributed through the rock mass. The molten sulfur collects in the bottom of the well and is lifted by air sent down through the 1-inch pipe. Various modifications of the process have been made to control the inflow of water from the quicksands and to distribute the hot water through the sulfur-bearing rock, but the process remains essentially as described. The sulfur, as it issues from the well, is piped to large bins made of rough plank, where it solidifies. These blocks of sulfur, which may contain several thousand tons, are

TABLE XI.—PRODUCTION OF SULFUR IN METRIC TONS

Year	United States imports	United States production	World production
1895.....	126,760	1,676	398,916
1900.....	167,328	4,630	581,282
1901.....	175,310	6,977	604,930
1902.....	176,951	7,565	552,996
1903.....	190,931	35,660	631,035
1904.....	130,421	196,588	767,249
1905.....	84,579	218,440	830,609
1910.....	30,544	259,699	787,732
1915.....	24,647	299,133	860,000
1920.....	44	1,542,059	1,941,052
1925.....	102	1,431,912	2,213,330

later broken up with explosives and shipped. The sulfur so produced is 99.5 to 99.8 per cent pure and is free from arsenic and selenium, but does contain small amounts of asphaltic material.

The effect of the Frasch process on the situation in the United States is strikingly pictured in Table XI.

Pyrites.—Iron pyrites is usually represented by the formula FeS_2 , and if pure should contain 53.4 per cent sulfur; but the mineral actually mined is variable in composition. Most manufacturers demand pyrites containing over 42 per cent sulfur. During the World War, material as low as 30 per cent sulfur was accepted. In 1926 the domestic production, which came mainly from California and Virginia, was about 30 per cent of the total consumption. Most of the imported pyrites come from Spain, although in some years considerable amounts have been imported from Canada.

Other Raw Materials.—In the metallurgy of most of the non-ferrous metals there is a step which involves roasting a sulfide ore, and this operation produces sulfur dioxide which might be used as a raw material for sulfuric acid manufacture. At present, however, this material is important only at zinc smelters, where considerable amounts of sulfuric acid are made from the waste gas from roasting zinc sulfide. In a few cases, sulfuric acid is made from the waste gas of copper smelters, but such plants are usually too far from consuming centers or else they produce gas so variable in composition as to be unsuitable for sulfuric acid manufacture.

In 1918 the production of acid in the United States from different sources was as follows:

TABLE XII.—SULFURIC ACID PRODUCTION ACCORDING TO RAW MATERIALS

	Tons	Per cent
From sulfur.....	3,580,000	48.0
From pyrites:		
Spanish.....	570,000	7.6
Domestic.....	950,000	12.7
Canadian.....	555,000	7.5
From zinc smelters.....	1,200,000	16.1
From copper smelters.....	600,000	8.1

These data represent unusual conditions due to the World War. More recent figures are not available, but at present the pro-

portion of acid made from sulfur is much higher than this table shows.

CHAMBER PROCESS

Sulfuric acid may be made by several processes, of which the most important are the chamber process and the contact process. A general outline of the chamber process is given in Fig. 12, which is purely diagrammatic and indicates only the most important elements in the process. Sulfur is burned with sufficient excess air so that the concentration of oxygen is slightly greater than that of sulfur dioxide. Sulfuric acid and sodium nitrate are mixed in the niter pot, which is placed in the flue carrying the hot burner gas. The nitric acid vapor so formed is carried into the stream of gas and reduced to oxides of nitrogen. The gas mixture then passes to the base of the Glover tower, down which acid is flowing. The gas rises through this tower, concentrating the acid, thereby becoming cooled and picking up considerable water vapor. From the top of the Glover tower the gases are conducted to the lead chambers, of which there may be from four to eight, although only two are shown in the diagram. Intermediate towers may or may not be placed between the chambers. Water is introduced into the top of the chambers, either in the form of spray or steam. In the chambers sulfur dioxide, oxygen, water, and the oxides of nitrogen react to form sulfuric acid, which collects in the bottom of the chambers and is drawn off as chamber acid of about 50° B \acute{e} . At the end of its passage through the chambers, the gas has lost most of its sulfur dioxide, but still contains oxides of nitrogen. These are recovered in the Gay-Lussac tower by absorption in a stream of cold 60° acid introduced at the top. The residual gas, consisting largely of nitrogen and oxygen, is discharged into the air from a stack.

The chamber acid is fed to the top of the Glover tower, and in its passage down this tower is concentrated to about 60° B \acute{e} . From the base of the Glover tower it passes through a series of coolers. Part of the cooled acid is drawn off as product, but a considerable proportion is sent to the top of the Gay-Lussac tower to absorb oxides of nitrogen. The acid drawn from the base of the Gay-Lussac tower is called "nitrous vitriol." This is taken to the top of the Glover tower; and in its passage down through the Glover tower the oxides of nitrogen are displaced and returned to the gas stream. Consequently, oxides of

nitrogen which are added by the niter pot merely serve to make up losses and are only a small fraction of the total amount of

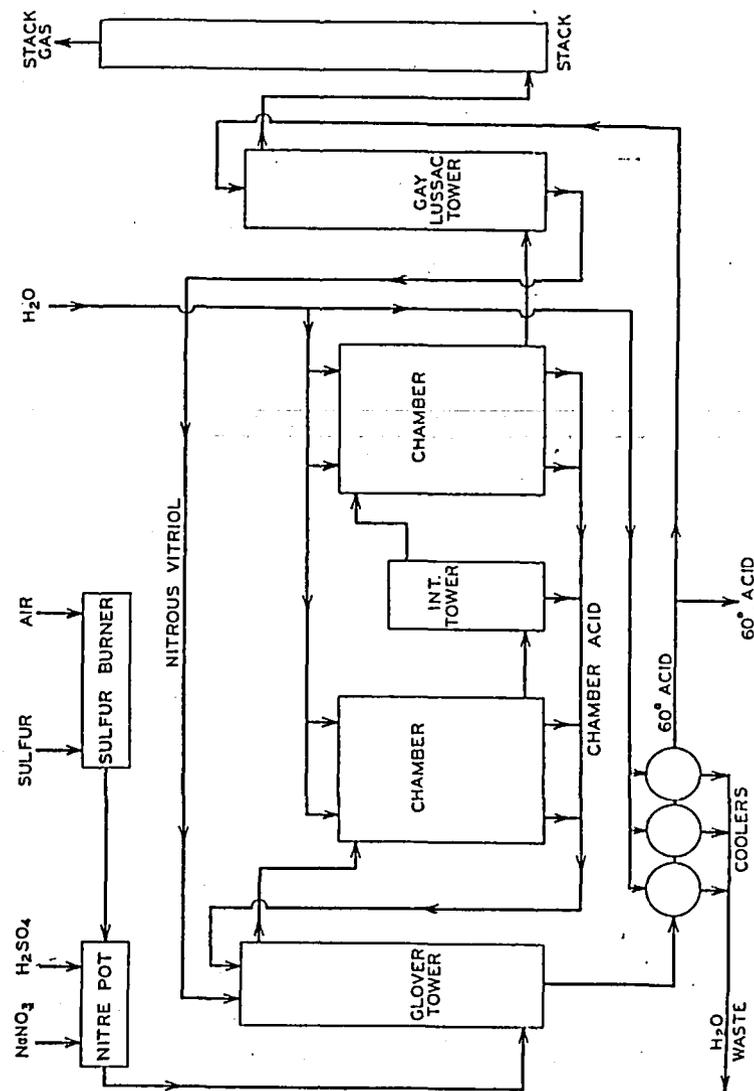


Fig. 12.—Flow sheet of chamber process for sulfuric acid.

oxides of nitrogen in the system. If the plant produces only 50° acid, chamber acid is withdrawn as the principal product

and is not sent to the Glover tower. In such cases, water is fed to the top of the Glover tower to supply the water which would otherwise be added in the form of chamber acid.

Sulfur Burners.—A successful sulfur burner must fulfil several requirements. As a consequence of the low heat of combustion and the high vapor pressure of sulfur, the burner must expose a large surface of molten sulfur; minimize loss of heat by radiation; provide secondary air in the zone of high temperature to burn sublimed sulfur; and facilitate the removal of non-combustible floating impurities such as ash and asphaltic matter.

These conditions are met in a wide variety of apparatus. Possibly the simplest sulfur burner consists merely of a large brick chamber. A cast-iron pan about 5 inches deep, into which sulfur may be charged, is set in the front of this chamber. The pan should have an area of about 30 square feet per ton of sulfur burned per day. Air for primary combustion is admitted over the pan. This air not only burns sulfur in the pan; but carries from the pan considerable sulfur vapor which burns in the rear of the chamber. Secondary air is admitted under the pan and mixes with the primary products in the rear. By regulating the distribution of air from these two inlets, it is possible to control the temperature of the molten sulfur, and introduce any desired proportion of secondary air.

The older burners, in which the pan was set on the floor, were not successful because it is not possible to secure complete combustion if all the air is admitted as primary air. As the quantity of air entering over the sulfur is increased, this merely increases the total quantity of sulfur burned and sublimed. At any given temperature, there will be an equilibrium between air and sulfur, in accordance with which the air will carry a certain proportion of sulfur vapor. Increasing the volume of primary air increases the quantity of air which can carry sublimed sulfur. This also increases the rate of combustion, thereby increasing the temperature and consequently the vapor pressure of the sulfur, with correspondingly increased sublimation.

A method of burning sulfur, which has been recently introduced but which has not yet become general, is to spray molten sulfur into a combustion chamber exactly as fuel oil is sprayed. Here, it is possible to admit all the air in one stage, because the sulfur may be fed at a regulated rate, so that an excess will not be available for sublimation.

The Glens Falls sulfur burner (Fig. 13) consists of a horizontal steel cylinder with conical ends, revolved on two sets of rolls. Sulfur is fed at one end through a worm-feed mechanism, and primary air is admitted at the same place. The heat of combustion melts the sulfur within the cylinder. The rotation of the cylinder distributes this sulfur in a thin film on the inside of the apparatus, and also causes it to shower in drops through the hot gas. The discharge end of the cylinder fits into a combustion chamber, and secondary air to burn sublimed sulfur is introduced here by a sliding damper. The agitation of the sulfur prevents the formation on its surface of a film of impurities which might slow down combustion. The cylinders vary from 20 inches by 4 feet-0 inches to 4 feet-0 inches by 20 feet-0 inches; and have a capacity of one ton of sulfur per 24 hours for each 24 cubic feet of cylinder volume.

The *Vesuvius* sulfur burner is shown in Fig. 14. It consists of a number of superimposed shallow cast-iron trays *A* set in a brick-lined steel shell. Sulfur is charged into a melting chamber *B* at the top, and is fed intermittently to the burner by opening the plug valve *C*. Each tray is provided with openings *D*. Successive trays are so placed that their openings come on opposite sides of the burner, so that the sulfur cascades from tray to tray. Air is admitted under the bottom tray and rises through these same openings. At

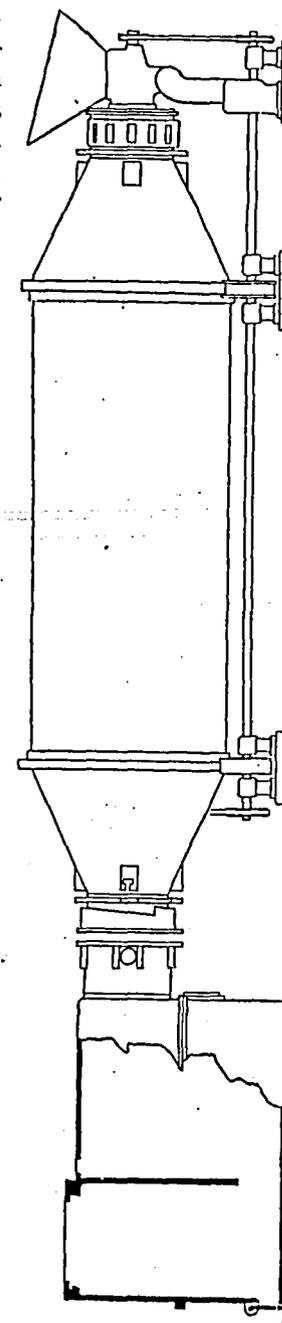


Fig. 13.—Glens Falls sulfur burner.

the level of each tray there is a door *E* through which some air may be admitted at each level. The exit pipe contains a damper *P* to admit secondary air into the flue. This flue leads into a firebrick-lined secondary combustion chamber *G* where sublimed sulfur is burned. This burner is made in sizes from 4 to 6 feet inside diameter, and burns 1 ton of sulfur per 24 hours for every 15 to 20 square feet of tray area.

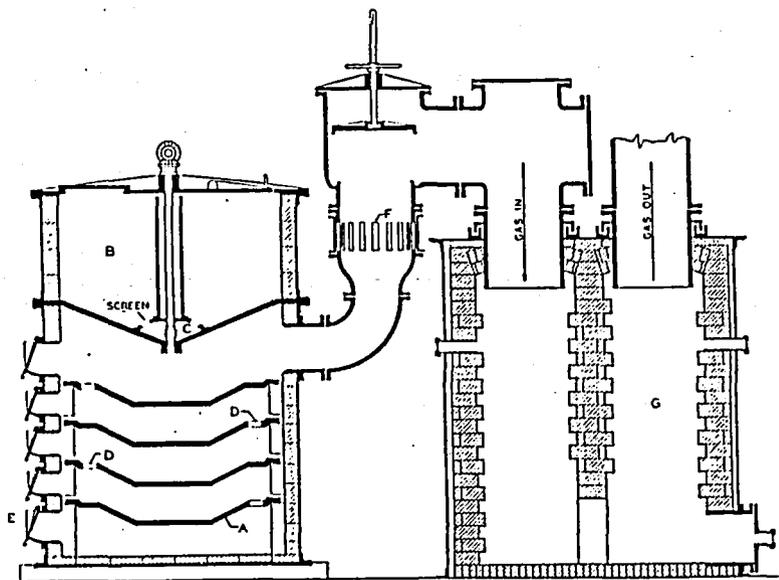


Fig. 14.—Vesuvius sulfur burner.

Pyrite Burners.—The type of burner which is used depends upon the size of the pyrites, coarse lumps and fine material requiring different types of burners.

Lump pyrite burners are simply brick-lined fire boxes about 6 feet long and 4 or 5 feet wide, with grates constructed of straight square bars. Since the production of uniform gas and the yield of a maximum amount of sulfur dioxide requires careful attention to the fires, the individual furnaces are made small. The heat of combustion of pyrites is low and hence it is essential that radiation losses be minimized. The furnaces are therefore set in batteries, each battery consisting of two rows, back to back, with a flue between. In order to secure uniform and complete combustion, the depth of fire bed must be considerable and the air must be preheated. This latter is

accomplished by maintaining a layer of hot cinders on the grates. About 50 square feet of grate area is required to burn 1 ton of 45 per cent sulfur ore per day.

Burners for fine pyrites have been made in a wide variety of designs. The principal features are shown in Fig. 15. The furnace consists of a brick-lined steel shell in the form of a

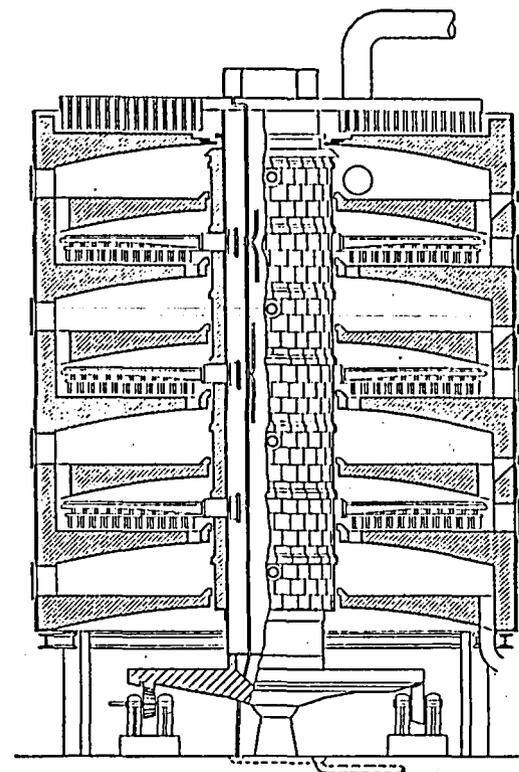


Fig. 15.—Burner for fine pyrites.

vertical cylinder 10 to 25 feet in diameter, in the axis of which stands a slowly rotating shaft. In the interior of this cylinder are constructed a number of superimposed firebrick hearths. The central shaft carries two or more arms for every hearth. Rabblers on these arms are set at such an angle that they draw the ore toward a central opening in every alternate hearth, and push it toward an opening near the circumference of the other hearths. The shaft and the rabble arms are cooled, and the different designs differ in the method of cooling, the provisions

for making repairs, and similar details. Most of the air for combustion is introduced at the bottom hearth and rises counter-current to the flow of material. The air is preheated by the burned cinder on the lower hearth. Combustion takes place on the intermediate hearths and the descending pyrites are preheated by the hot gases on the upper hearth. If the burner temperature becomes too high, additional air is introduced at intermediate hearths. These furnaces require about 100 square feet of hearth area per ton of ore per day.

Experience has shown that the best results in the chamber plant are obtained when the gas from the sulfur burners contains 8.5 to 9.0 per cent sulfur dioxide. This corresponds to 12.0 to 12.5 per cent free oxygen. In the burning of pyrites, part of the oxygen of the air is combined with the iron. Maintenance of the proper ratio of sulfur dioxide to oxygen, therefore, results in pyrites burners being operated to give a gas of 7.0 to 7.5 per cent sulfur dioxide.

Niter Supply.—The usual method of replacing losses of oxides of nitrogen is to charge sulfuric acid and sodium nitrate, in approximately equimolecular proportions, into a cast-iron vessel known as a *niter hog*. This is set in the flue carrying the hot gas from the burner to the Glover tower, to supply the heat to carry out the reaction and vaporize the nitric acid. When the nitric acid vapor mixes with the burner gas it is reduced. The reaction is probably



Sometimes in place of the niter hog, chambers lined with acid-proof masonry are used; or if the plant is large, retorts such as are used for the manufacture of nitric acid (p. 91).

In the manufacture of nitric acid, a certain amount of the product is obtained in the form of solutions too dilute to be marketable. This dilute acid may be added directly to the Glover tower, where it is decomposed by sulfur dioxide according to the reaction already given.

In recent years there has been a pronounced tendency to supply oxides of nitrogen to the chamber process by the oxidation of ammonia^(4,5) (see p. 111).

In this process a mixture of ammonia and air is passed over heated platinum gauze, and if the proper conditions are maintained the nitrogen of the ammonia is almost quantitatively

oxidized to NO. The apparatus is compact and easily operated. The supply of oxides of nitrogen to the process can be accurately and instantly regulated by turning a single valve; and at present prices of ammonia and saltpeter, it is much cheaper than the older methods.

The apparatus consists of a blower for furnishing air, a catalyst chamber, and a heat interchanger. If liquid ammonia is used, the air is preheated in the heat interchanger, and the ammonia is introduced through a control valve just before the mixture enters the catalyst. The heat of reaction is sufficient to preheat the incoming gases to the reaction temperature. If aqua ammonia is used, the air first passes up a small column down through which aqua ammonia is passed. The mixture of air and ammonia is then preheated, but to avoid decomposition of the ammonia the heat exchanger must be made of nickel or aluminum.

The losses of oxides of nitrogen in the whole process, calculated as sodium nitrate, amount to about 4 per cent of the total weight of sulfur burned. This holds true for plants operating on sulfur or a good grade of pyrites. Plants operating on metallurgical gases of varying compositions may use as high as 8 or 9 per cent sodium nitrate. The niter loss also varies with the method of plant operation, since forcing the plant to high capacities results in a proportionately increased loss of oxides of nitrogen. With uniform operation at moderate rates the loss may be held down to 2 per cent.

Dust Collectors.—When pyrites are burned, if the fine material carried over with the gases were not removed, it would soon clog the Glover tower. The usual method is to introduce, between the burners and the Glover tower, a chamber whose cross-section is considerably larger than the gas flue. This chamber may be empty and depend merely on a decrease in gas velocity to drop the suspended particles; or it may be provided with baffles. The cross-section should be such as to reduce the gas velocity to about 3 feet per second, and it should be long enough to give the gases a total time in the chamber of 0.5 to 0.75 minutes.

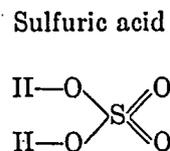
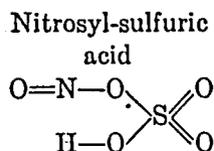
In some plants, especially those operating on smelter gases, the Cottrell system of electrical precipitation is used. This requires cooling and humidification of the gases. It consists in passing the gases through paths of relatively small cross-section,

each carrying a central electrode. Between this electrode and the wall of the conduit a high-potential unidirectional electrostatic field is maintained. The solid particles are electrified and attracted to one of the poles. Provision is made for jarring the electrodes at intervals so that the accumulated dust falls into a hopper below.

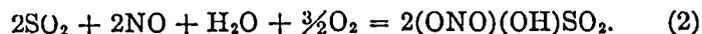
The Glover Tower.—From a study of Fig. 12 and the description which accompanies it, it will appear that the Glover tower has several functions. Among these may be mentioned:

1. Cooling the burner gases.
2. Concentrating chamber acid.
3. Returning to the system oxides of nitrogen which have been recovered in the Gay-Lussac tower.
4. Supplying water vapor to the first chamber. Before proceeding to a more detailed discussion of these it will be necessary to consider some reactions of general importance.

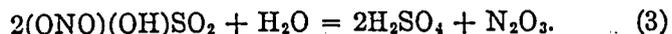
The reactions which take place in the chamber process have been the subject of many controversies, but the theory advanced by Lunge⁽⁶⁾ has had the widest acceptance and has withstood criticism. Nevertheless, it is not complete, and there are many details of the operation of the chamber process which are not yet fully understood. According to Lunge, a very important place is held by a compound called nitrosyl-sulfuric acid, whose relation to sulfuric acid is shown by the following structural formulas:



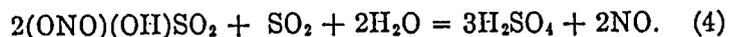
In the presence of sulfur dioxide and some free oxygen, this acid can be formed by the following reaction:



This compound is easily hydrolyzed, liberating sulfuric acid and N_2O_3 according to the reaction



It is also easily reduced by SO_2 according to the reaction



High temperatures not only favor a more rapid rate of reaction, but also give an equilibrium corresponding to more complete decomposition of the nitrosyl-sulfuric acid. It is obvious that both reactions (2) and (4) are favored by high concentrations of sulfur dioxide; reaction (2) taking place where concentrations of NO are high, and reaction (4) where they are low.

It will be apparent, therefore, that the Glover tower is adapted to accomplish the recovery of nitrogen oxides from Gay-Lussac acid by hydrolysis in the upper part of the tower, and by reduction by means of sulfur dioxide in the lower portions of the tower. Gay-Lussac acid is fed into the top of the Glover tower and in addition there is added the comparatively dilute chamber acid; or should the chamber acid be taken off as a separate product, water is added in its place. Hot burner gases entering the bottom of the tower and carrying a relatively high content of sulfur dioxide are able to decompose, according to reaction (4), any nitrosyl-sulfuric acid which may have reached the bottom of the tower. Thus, the acid issuing from the base of the Glover tower should contain only a trace of oxides of nitrogen. As the burner gas rises through the tower, it carries not only the nitric oxide from the niter pot, but increasing amounts of nitric oxide liberated from Gay-Lussac acid. This makes possible the direct synthesis of nitrosyl-sulfuric acid by reaction (2) at certain intermediate zones in the tower. Because of the high temperature of the gas it is able to concentrate the acid which it meets and, therefore, as it ascends, it also carries increasing concentrations of water vapor. This, combined with the dilution caused by chamber acid or water at the top, gives a zone in the upper part of the tower where nitrosyl-sulfuric acid is decomposed by hydrolysis. Thus, it will be seen that in addition to the functions previously mentioned, the Glover tower has another and very important one; namely, the synthesis of sulfuric acid. The acid formed in the tower may be as much as 20 per cent of the total output of the system.

The construction of the Glover tower varies considerably, but present practice favors a tower built of acid-proof brick, sheathed with lead and resting in a lead pan (Fig. 16a). On this lead pan is laid an acid-proof masonry floor, which supports the walls of the tower and also arches, which in turn support packing material with which the tower is nearly filled. A special distribution

device at the top of the tower insures uniform wetting of the packing with the acid.

All the reactions taking place in the Glover tower involve the interaction of a liquid and a gas. It is, therefore, necessary that these two phases be brought into as intimate contact as possible

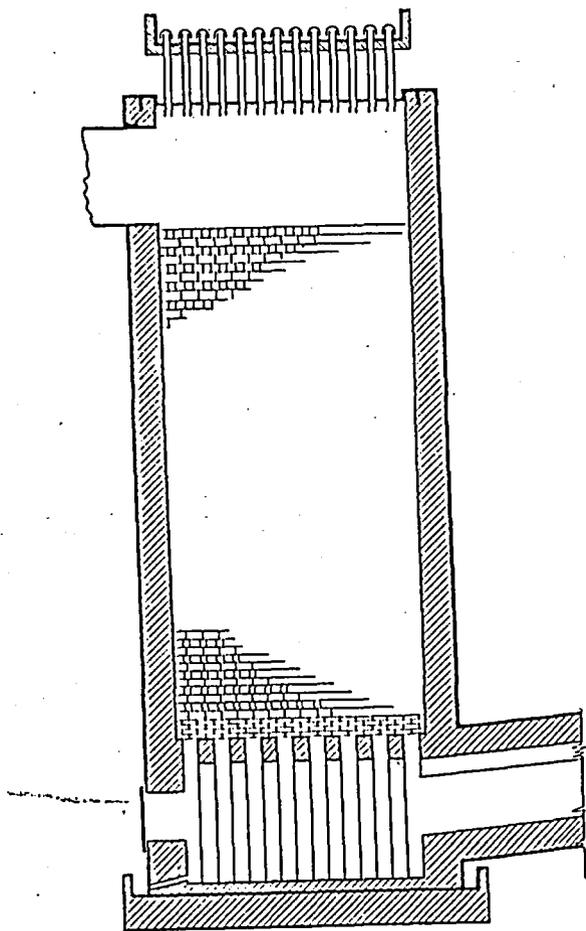


FIG. 10a.—Details of chamber-plant construction: Glover tower.

in countercurrent. For this purpose, the liquid is filmed out over the packing material in the tower while the gas is forced to pass up through this packing.

At the high temperatures of the Glover tower all these reactions are very rapid and a relatively short time of contact is

sufficient. Consequently, a rather coarse packing with relatively large free spaces and filling only a short section of the tower (15 to 25 feet) is satisfactory. Ordinary practice calls for 0.10 to 0.15 cubic feet of packed space per pound of sulfur burned per 24 hours, and a gas velocity of approximately 1 cubic foot per second per square foot of tower cross-section.

The gas inlet at the bottom of the tower opens into an empty space, which is provided to give more uniform distribution of gas through the packing. For the same purpose an unpacked space is left at the top of the tower. The packing consists of broken quartz or stoneware shapes, supported on arches of acid-proof brick. Since the cross-section of the tower is great compared to the height of the packed section, special devices must also be employed to insure complete distribution of the chamber acid and nitrous vitriol over the packing. These usually consist of a considerable number of openings in the top of the tower and a number of pipes leading to these from a central distributing box.

Lead Chambers.—The lead chambers are essentially large vessels which allow space, and therefore time, for the major reactions to take place before the gases leave the system. The gases entering the first chamber from the Glover tower contain water vapor, and a relatively high concentration of sulfur dioxide and free oxygen. The oxides of nitrogen at this point are almost entirely NO, as shown by the fact that the contents of the first chamber are usually without any trace of red oxides.

The reactions by which sulfuric acid is made in the chambers result in the evolution of heat, so that the central portions of the chambers are always warmer than the outer portions which are exposed to the cooling influence of the surrounding air. The chambers are filled with small floating particles of mist which circulate about with the chamber gases, rising in the central portions of the chambers and falling near the sides. These mist particles consist of nitrosyl-sulfuric acid and sulfuric acid of varying dilutions. Since the partial pressure of water vapor within a given chamber is more or less uniform, and since these particles are hotter in the central portion of the chamber, they will, therefore, be more concentrated in the central part of the chamber and more dilute toward the walls. In the central areas sulfur dioxide, nitric oxide, and oxygen can unite to form nitrosyl-sulfuric acid; whereas at the walls, where the temperature is

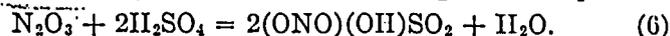
lower, water vapor condenses on the drops, diluting them, hydrolyzing the nitrosyl-sulfuric acid, and liberating oxides of nitrogen. Any N_2O_3 which is liberated must recombine with great rapidity with sulfur dioxide and water, forming more nitrosyl-sulfuric acid; for the gas in the first chamber is substantially colorless.

Much of the difficulty in assembling a coherent theory of the chamber process centers around the question of which oxides of nitrogen are present and what their various functions may be. The oxides of nitrogen involved in the process are commonly considered to be three in number; NO which is colorless, NO_2 which is reddish, and N_2O_3 which is deep red. At the temperature of the chambers, N_2O_3 cannot exist except in very small concentrations. If it is formed by the hydrolysis of nitrosyl-sulfuric acid it must almost completely dissociate according to the reaction:

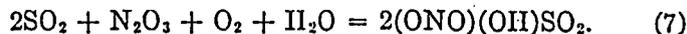


That NO_2 , except such as results from this dissociation, does not enter into reactions in the chambers, is evidenced by the fact that an excess of NO_2 over NO is never found in the chamber gases. Any NO_2 which is present probably reacts not as such, but by combining with NO to form N_2O_3 . Consequently, the assumption that only NO and N_2O_3 or its equivalent are present, gives a satisfactory explanation of the reactions in the chambers.

It has been observed that the contents of the earlier chambers are white or colorless, while the later ones show an increasing reddish color. This indicates the absence of N_2O_3 from the first chamber. This is usually explained by assuming the formation of nitrosyl-sulfuric acid according to the equation:



As the gas proceeds through the chambers, its temperature is lowered and at the same time the sulfur dioxide concentration is decreased, the decomposition of nitrosyl-sulfuric acid according to equation (4) decreases, its hydrolysis by water with the formation of N_2O_3 increases, and thus the increasing color is explained. Equation (2) calls for the synthesis of nitrosyl-sulfuric acid by nitric oxide and oxygen. In the presence of lower concentrations of sulfur dioxide and at lower temperatures, the NO in this equation may be replaced by N_2O_3 as follows:



It has been stated above that at temperatures existing in the chambers N_2O_3 exists only in very small concentrations. The residual concentration of N_2O_3 at equilibrium is sufficient for reaction (7), thereby removing N_2O_3 from the gas phase and causing NO and NO_2 to react with the formation of more N_2O_3 .

The reactions which have been discussed result in the removal of water from the chamber gases to form sulfuric acid. The water vapor supplied by the Glover tower is usually sufficient for the first chamber, but in succeeding chambers water must be added as steam or fine spray.

At various times small intermediate towers sometimes empty and sometimes packed, have been built between the chambers. The original theory was that the purpose of these towers was to cool the gases, but this has been proved incorrect. Probably their most important function is to scrub out sulfuric-acid mist. If this mist in the chambers becomes too concentrated or too cold, it may absorb N_2O_3 directly according to reaction (6). This increases the quantity of nitrosyl-sulfuric acid in the liquid and decreases the concentration of oxides of nitrogen in the gas. By reducing the proportion of acid mist in the gas in the later chambers, a larger concentration of these oxides is left in the gas phase, and the use of an intermediate tower therefore increases the quantity of acid made in the following chamber.

Chamber Construction.—The usual lead chamber is a rectangular vessel of sheet lead supported on a suitable framework. These chambers may be 50 to 150 feet long, 16 to 26 feet high, and 20 to 30 feet wide. There are usually three to six chambers; and they may all be of the same size, but it is more common to make the first chamber longer than the others. For a given method of working, the total capacity in cubic feet of chamber space per pound of sulfur burned is fairly constant. The older chambers had a wood framework, but modern construction employs steel. Because of the tendency of lead to crawl (deformation beyond the elastic limit) it must be securely fastened at frequent intervals. This is usually accomplished by burning tabs of lead to the side walls at intervals not less than 3 feet apart each way, and securely fastening these tabs to the supporting framework (Fig. 16b). The top of the chamber is hung in a similar manner. Through the top project spray nozzles for the introduction of water mist or, preferably, steam. The

bottom of the chamber is a pan with upturned edges which are burned to the bottoms of the side walls. At intervals along the side walls a gutter is burned on the inside with a small connection to the outside of the chamber. A portion of the

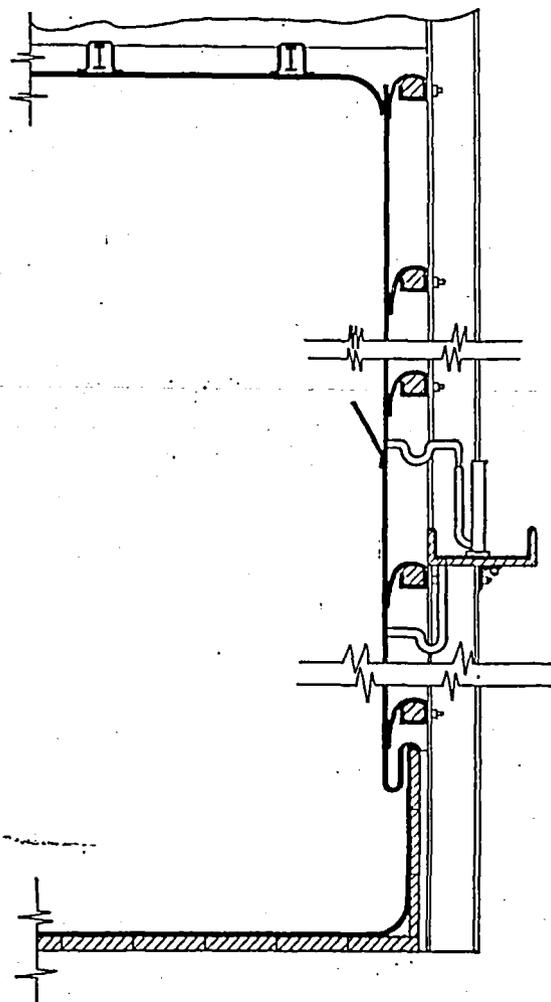


Fig. 16b.—Details of chamber-plant construction: chamber construction.

acid condensed on the chamber walls drains into this gutter and drips from a spout outside the chamber. The density of these drips, together with the temperatures of the chambers, furnish the information by which the process is usually controlled.

Gay-Lussac Tower.—If the chambers are properly operated there will be a very small concentration of sulfur dioxide in the gas leaving the final chamber, and there should have been no loss of oxides of nitrogen up to this point. Since the Gay-Lussac tower is fed at the top with cold 60° acid, conditions are favorable to reaction (6). It is obviously important that the concentration of sulfur dioxide be kept low, otherwise equation (4) would take place with loss of oxides of nitrogen. On the other hand, if the sulfur dioxide be exhausted before the gas leaves the last chamber, nitric acid will form in the last chamber, condensing on the chamber walls and corroding them. Exhausting the sulfur dioxide will also permit the excess oxygen, required for the chamber reactions, to oxidize nitric oxide to nitrogen dioxide in excess of that corresponding to N_2O_3 . The excess nitrogen dioxide will not form nitrosyl-sulfuric acid, and is only slightly soluble in sulfuric acid.—The function of the Gay-Lussac tower is, therefore, relatively simple and is represented in normal working by equation (6). Some oxides of nitrogen are always lost from the top of the Gay-Lussac tower, due partly to the presence of SO_2 (equation (4)), partly to inability to carry equation (6) to completion, and partly to the presence of an excess of NO_2 .

The Gay-Lussac tower is usually about the same cross-section as the Glover tower, but since the temperature is low and the reactions are less rapid, a longer time and a more intimate contact between gas and liquid are required to bring them even approximately to completion. Therefore, the packing is finer than in the Glover tower so as to expose more surface per unit volume, and the length of this packed space is usually at least twice that of the Glover tower. Since it is inconvenient to build a single tower so high, there are usually two Gay-Lussac towers operating in series. The volume of the packed space in the Gay-Lussac depends on the effectiveness of the packing. It is also inversely proportional to the volume of chamber space per pound of sulfur burned per 24 hours. The product of this volume and the volume of packed space in the Gay-Lussac should be 3, for average stoneware shapes.

The volume of 60° acid pumped over the Gay-Lussac is one to three times the volume of acid made in the chambers, the actual quantity being so adjusted that the acid leaving the tower will contain 1 to 2.5 per cent of N_2O_3 by weight. More intensive

working of the chambers, which requires a higher concentration of oxides of nitrogen in the chambers, will therefore require more acid for the Gay-Lussac.

Movement of Gases.—It is necessary to provide some means for moving the gases through the chambers and towers and creating a draft for the burners. This may be done by interposing a fan at some place in the system, as between the burners and the Glover tower, or on the exhaust gases from the Gay-Lussac tower. In place of a fan, the gases from the Gay-Lussac tower may be conducted into the boiler stack. This has the advantage of eliminating the maintenance of fans.

Transportation of Acid.—Since very large quantities of acid must be handled in a chamber plant of even moderate size, the apparatus for moving this acid is of importance. One very simple device, formerly used almost entirely and still extensively used, is the acid egg. This is a cast-iron vessel provided with three necks. One of these serves as an acid inlet, another is provided with a pipe dipping to the bottom of the egg and serving as an acid outlet, and the third serves as an air inlet. Acid is allowed to flow in until the egg is filled, when the supply of acid is cut off, air is turned on and the charge blown out. The valves necessary for carrying out these operations may be entirely manually operated, but in more recent designs they are semiautomatic or entirely automatic so that the egg operates without attention. Many modern plants handle acid entirely with centrifugal pumps. These pumps are available in a number of designs, either in hard lead or Duriron, and have proven entirely satisfactory. Sixty-degree acid or stronger, free from dissolved oxides of nitrogen, can be handled in specially designed cast-iron centrifugal pumps.

Coolers.—The hot 60° Bé. acid from the base of the Glover tower must be cooled because the larger proportion is to be sent to the Gay-Lussac tower. The coolers consist of a series of water-jacketed lead tubs, filled with lead cooling coils. This design of cooler facilitates the removal of sulfur carried from the base of the Glover tower; and as the Glover acid is quickly mixed with partially cooled acid, corrosion of the lead is minimized.

Special Systems.⁽⁷⁾—In the previous discussion, it has been developed that acid formation in the chamber process depends on the mixing of gases and spray in the chambers, and on the dissipation of the heat liberated by the reaction. In the ordinary

lead chambers, mixing takes place chiefly by diffusion and convection, and the heat of reaction is dissipated by radiation from the walls to the surrounding air. Such chambers use from 12 to 30 cubic feet of chamber space per pound of sulfur burned per 24 hours. It is obvious that the rate of reaction could be increased and the amount of chamber space decreased if devices

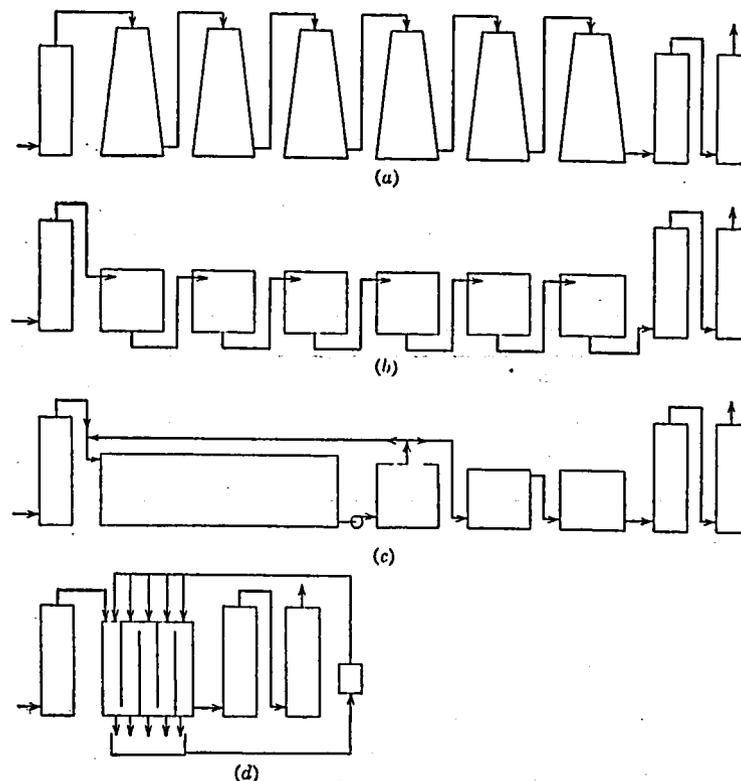


FIG. 17.—Special chamber systems. (a) Mills-Packard; (b) Meyer tangential; (c) Pratt; (d) Anaconda.

were added for mixing the gases, for removing heat, or for bringing the gas and liquid phases more thoroughly into contact with each other. A number of systems have been devised for accomplishing some of these aims; and while none of them has been adopted to the exclusion of the standard process, they all show marked advantages over the usual chamber system.

The *Mills-Packard* system (Fig. 17a) has been used mainly in England, though to some extent on the continent and in the

United States. It employs lead chambers in the form of truncated cones, of 7,000 to 18,000 cubic feet each. The particular feature of the process is that a film of water is allowed to trickle down the outer surface of the cone to remove the heat of reaction. This results in rapid cooling and condensation on the inner surface of the chambers, so that Mills-Packard systems operate with 3 to 5 cubic feet of chamber space per pound of sulfur burned.

The Meyer tangential chambers (Fig. 17b) are in the form of vertical cylinders 33 feet in diameter. The gases are introduced near the top by a tangential inlet and are removed from the center of the bottom. The resultant whirling serves to mix the gases more intimately and results in a high rate of working, requiring only 6 to 7 cubic feet of chamber space per pound of sulfur burned.

The above systems have not been used to any great extent in the United States, but there have been certain developments in this country along similar lines. In the Pratt system (Fig. 17c) the chambers are reduced to three or four in number and 80 per cent of the total chamber space is in the first chamber. Following this first chamber is a "converter shaft" about 25 feet high and 25 feet square, packed with broken quartz. Water for the process is sprayed in at the bottom of this shaft. A fan draws gas and mist from the bottom of the first chamber, passes the mixture up through this tower, and returns gas to the head of the first chamber. There is also, of course, the usual circulation from the first chamber to the later ones. The Pratt system results in a higher velocity of the gas in the first chamber, and a thorough mixing and scrubbing in the converter. The average plant running on the Pratt system uses 7 to 9.5 cubic feet of chamber space per pound of sulfur burned.

The most radical development is the Anaconda packed cell system (Fig. 17d).⁽⁸⁾ This is based on the logical assumption that, since the formation of sulfuric acid results from reactions between the gas phase and the liquid phase, the logical thing to do would be to make the contact between the two phases as intimate as possible and to subject the gases to the maximum possible amount of mixing. In order to insure that the reaction should proceed more rapidly, between two and three times the usual concentration of oxides of nitrogen is maintained in the system.

The burner, niter hogs and Glover tower are the same as for an ordinary chamber plant. Instead of the chambers, there are five towers or cells, packed with acid-proof brick set on edge, and with either lead or acid-proof masonry walls. These five towers are built as one common block to decrease space and cost of construction. Following these are four Gay-Lussac towers of the ordinary type.

The cells have an acid circulation system consisting of a receiver at the bottom, a pump, and a distributing tank at the top. Water is added to these tanks as may be necessary to keep the concentration at about 50° Bé.; so that no sulfur dioxide or oxides of nitrogen will dissolve in this acid. Some of this acid is drawn off to the Glover tower, and in all other respects except the circulation of acid over the cells the operation is exactly like that of the ordinary chamber plant. The reactions proceed so rapidly that this plant will operate with less than 1 cubic foot of chamber space per pound of sulfur burned. The loss of oxides of nitrogen is, however, rather high; amounting to possibly 4.5 per cent.

Purification of Sulfuric Acid.—When acid of high quality is desired, it is usually sufficient to specify that it be made from brimstone. If acid of the highest purity is needed, it can be obtained by specifying that it must be made by the contact process. The very rigorous purification which the gas receives in the contact process means that contact acid will always be appreciably purer than chamber acid. In some cases where chamber acid is made from pyrites or blende, it may have to be treated to remove arsenic.

This is best carried out by passing hydrogen sulfide through acid of 50 to 53° Bé. It may be done in towers, or in special apparatus in which rapidly rotating paddles subdivide the acid and bring it into contact with the gas. The sulfide precipitate is then removed by sand or coke filters. There are uses for impure acid, and in most plants in the United States, purification is not necessary.

CONCENTRATION OF SULFURIC ACID

Usually, chamber plants are so located that they dispose of most of their acid at 53 or 60° Bé. The demand for acid of 66° or stronger is usually met with contact acid. There are cases, however, where it is desirable to concentrate either chamber

acid or Glover tower acid to 66°. This is at present done by one of two methods. One of these (the cascade system) employs indirect heating; in the other (the tower system) hot gases are brought into direct contact with the acid.

The Cascade System.—Figure 18 shows a type of cascade system commonly used in this country. This consists of a number of dishes of fused silica set one above the other in refractory brick, so that the acid flows from dish to dish in series. These are mounted over a firebox in such a way that the products of combustion pass up under the cascade in counter-current. The upper pans in the series may be rectangular and

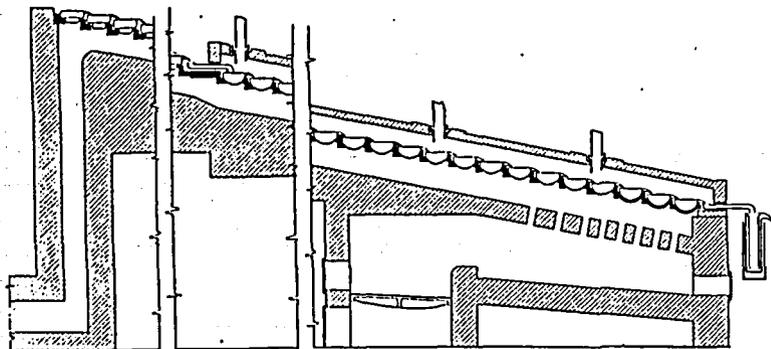


FIG. 18.—Cascade concentrator for sulfuric acid.

flat-bottomed, but the greater proportion are approximately hemispherical basins, from 12 to 18 inches in diameter, with a projecting lip on one side. Because of the low coefficient of thermal expansion of fused silica, these dishes may be set so that their bottoms are in direct contact with flue gases.

If chamber-acid is being concentrated, the upper third of the cascade may be uncovered, as these dishes then give off practically only water vapor. When concentrating chamber acid, the lower two-thirds of the cascade (and when concentrating Glover acid, the whole of the cascade) must be covered, as the vapors from this part of the system carry too much acid to be discharged into the air. These vapors, under carefully controlled conditions, can be largely condensed to yield a dilute acid of the highest purity, suitable for storage batteries. The residual fumes will be passed to towers, absorbed in water, and returned to the system. At the end of the cascade, the acid overflows

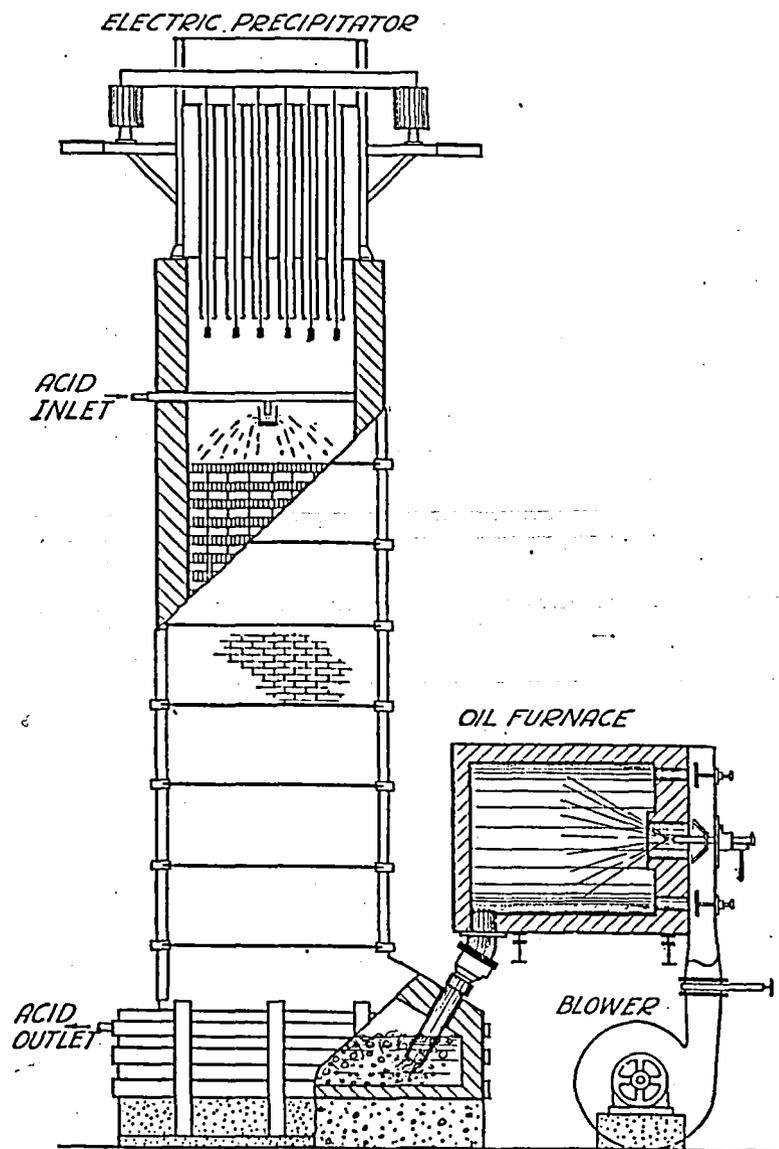


FIG. 19.—Chemico concentrator for sulfuric acid. (Courtesy Chemical Construction Company.)

into a series of large fused silica beakers set in vessels of water to cool the acid.

In some plants the fused silica parts of this system may be replaced with Duriron; and combinations are found of lead pans above and silica or Duriron vessels in the lower part of the cascade. Duriron or lead must be set in sand and not exposed to direct fire.

The Tower System.—The tower system, in which acid is brought into direct countercurrent contact with hot flue gas, may be illustrated by the Chemico concentrator (Fig. 19).⁽⁹⁾ Older variants of this system are the Gaillard and Kessler concentrators.⁽¹⁰⁾ These all operate on the same principle, and differ only in structural details.

The acid to be concentrated is fed at the top of the tower. The tower is filled with quartz or stoneware packing, and delivers the acid at the bottom to a pan. This pan is lined with acid-proof masonry, and is heated by the products of combustion from a gas or oil burner. At the back of this pan the concentrated acid overflows to coolers and a storage tank. The gas leaving the top of the tower contains considerable sulfuric-acid mist, and is therefore conducted through a Cottrell electrical precipitator. The acid collected by the precipitator drains back into the tower.

Tower concentrators are similar in operation to a Glover tower, and have a correspondingly large capacity with low cost of maintenance. When fired with gas or oil, the purity of the acid is not decreased in passing through the concentrator, and the product may be water-white if the tower is fed with chamber acid.

Figure-20⁽¹¹⁾ shows the equilibrium concentration of sulfuric acid in the vapor phase, corresponding to various concentrations in the liquid phase, at the boiling point at one atmosphere. It will be apparent that the vapor from boiling 66° Bé. acid would contain about 30 per cent sulfuric acid, whereas the vapors from 50° Bé. acid will be acid free. This explains why the upper part of a cascade system may be left open, while the lower part must be so enclosed that the vapor from it may be condensed and the acid recovered. Inert flue gas in the tower system lowers the partial pressure of the acid vapor and therefore concentration takes place at much lower temperatures. This results in a lower concentration of acid in the gas phase than that called for by

Fig. 20. Tower concentrators possess a further advantage in that they function in much the same manner as a rectifying column. Acid vaporized in the lower part of the tower is

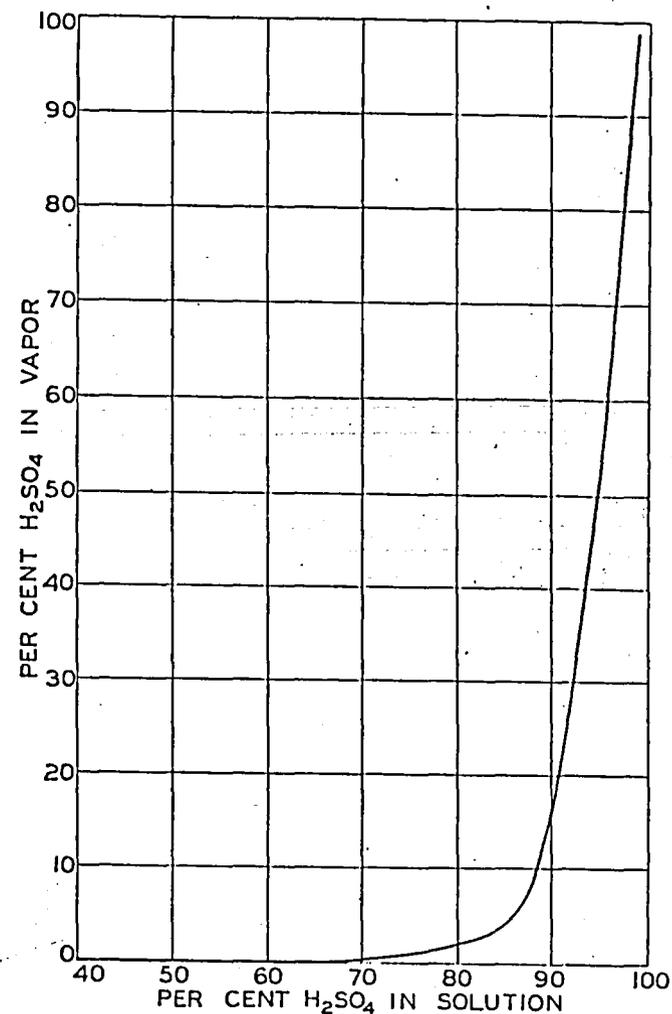


FIG. 20.—Concentration of sulfuric acid in vapor at the boiling point.

largely absorbed in the cooler and more dilute acid descending in the upper portions of the tower.

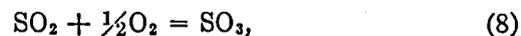
The tower concentrators, therefore, produce less fume to be condensed as dilute acid, cool the combustion gas to a lower

temperature, and discharge the concentrated acid at a lower temperature, than the cascade system.

THE CONTACT PROCESS

Many industries, especially those organic industries which involve nitrations, require high concentrations of sulfuric acid. While 66° B \acute{e} . acid may be obtained by the concentration of acid from the chamber process, sulfuric acid of 100 per cent or stronger cannot be made in this way. Such strong acids are made by absorbing sulfur trioxide in 66° acid. Sulfur trioxide was first obtained by the dry distillation of ferric sulfate or shale containing alum or other heavy metal sulfates. Difficulties in the production of large amounts of sulfur trioxide by these methods created a demand for a method for making it directly from sulfur or pyrites. The successful development of the oxidation of sulfur dioxide directly to sulfur trioxide, which was accomplished between 1890 and 1900, laid the foundations for what is now known as the contact process for the manufacture of sulfuric acid. The design of a successful contact acid plant was accomplished, however, only after a satisfactory understanding of the equilibrium between sulfur dioxide and sulfur trioxide.

Theory of the Contact Process.—From a consideration of the equation



it is obvious that at equilibrium the relative concentrations of the reacting substances at any particular temperature, are defined by

$$K = \frac{P_{\text{SO}_3}}{P_{\text{SO}_2}} \times \frac{1}{\sqrt{P_{\text{O}_2}}} \quad (9)$$

where these pressures refer to the partial pressures of the various gases, expressed in atmospheres, after equilibrium is obtained. (12)

This reaction is exothermic and consequently an application of Le Chatelier's theorem shows that the position of the equilibrium must shift with increasing temperature in such a way as to call for lower conversions of sulfur dioxide to trioxide. If the heat of the reaction at any one temperature and the specific heats of the reacting substances are known, it is possible to calculate the variation of K with temperature fairly accurately. With the best values for the constants it is found that

$$\text{Log}_{10} K = \frac{8,775}{t} - 4.46 \quad (10)$$

where t is temperature in degrees Rankine. Table XIII presents a series of values of K calculated from this equation and corresponding experimental values obtained by Knietzsch and Bodlander.

TABLE XIII.—EFFECT OF TEMPERATURE ON EQUILIBRIUM CONSTANT IN THE CONVERSION OF SO_2 TO SO_3

$t^\circ \text{C.}$	$t^\circ \text{F.}$	t° Rankine	K calculated	K observed	Observers
450	842	1,302	191.4	187.7	Knietzsch
500	932	1,392	70.0	72.3	Knietzsch
515	959	1,419	53.2	65.4	Bodlander
553	1,027	1,487	27.5	24.1	Bodlander
600	1,112	1,572	13.3	14.9	Knietzsch
610	1,130	1,590	11.5	10.5	Bodlander
700	1,292	1,752	3.55	4.84	Knietzsch
800	1,472	1,932	1.21	1.81	Knietzsch
900	1,652	2,112	0.20	0.57	Knietzsch

If 100 mols of burner gas containing a mols of SO_2 , b mols of O_2 , and c mols of SO_3 are brought into equilibrium at any given temperature, x mols of SO_3 will be formed. This will cause the disappearance of $0.5x$ mol of O_2 and x mols of SO_2 . The partial pressure of SO_3 in the resulting gas will then be

$$\frac{x + c}{100 - 0.5x},$$

because there has been a net contraction in volume of $0.5x$. In the same way the partial pressure of SO_2 in the resulting gases will be $\frac{a - x}{100 - 0.5x}$, and of O_2 , $\frac{b - 0.5x}{100 - 0.5x}$.

Substituting these values in the equation for K above we have the following:

$$K = \frac{x + c}{(a - x) \left(\frac{b - 0.5x}{100 - 0.5x} \right)^{1/2}} \quad (11)$$

For a particular value of K the corresponding value of x is most simply found by the method of trial and error. Several values may be assumed for x and substituted in the right-hand member of this equation. That value of x which gives the desired value

for K is the solution. Graphic interpolation may be used to shorten the work.

Rate of Reaction.—The above discussion is based on conditions which would obtain if equilibrium were reached, and says nothing about the time necessary to reach that equilibrium. Numerical data for these rates are still too fragmentary to include here,⁽¹³⁾ but all reactions increase in velocity considerably with moderate increases in temperature. In this particular case, even at temperatures above 1100° F., the rate of reaction is very slow. Although at higher temperatures the reaction may be more rapid, equilibrium, if reached, is at low concentrations of sulfur trioxide. By the use of a catalyst, however, the velocity of the reaction can be increased, so that at low temperatures where favorable equilibrium conditions exist, practical operation is possible.

Many substances catalyze this reaction more or less. In burning sulfur, practically no catalyst is present and negligible amounts of sulfur trioxide are formed. In burning pyrites, the Fe_2O_3 acts as a catalyst to a certain extent and small amounts of sulfur trioxide appear in the burner gas. Finely divided platinum is the best catalyst; and with this substance in an active condition, equilibrium can be substantially reached in a few seconds at temperatures from 750 to 850° F. Temperatures of this order correspond to an equilibrium so favorable that in actual practice conversions of 98 per cent or better are possible. Recently, vanadium silicates have been used as a catalyst in one plant, with results equal to those obtained with platinum.⁽¹⁴⁾

Obviously, in practical operation the catalyst is a factor of prime importance. The commercial processes are classified on the basis of the catalyst used. Iron-oxide cinder from the burning of pyrites is used as a catalyst in the Mannheim process.⁽¹⁵⁾ This gives a partial conversion of the sulfur dioxide. The resulting gas is then purified and further conversion obtained with a platinum catalyst. This process involves a complicated plant and is not used in the United States.

The other processes use a platinum catalyst only. Various names, such as Badische, Schröder-Grillo, and Tenteleff, have been applied to systems involving different methods of preparing the catalyst and specific plant flow sheets. The distinction between these processes, as they are exemplified in more modern plants, is no longer pronounced; and, in fact, variations between

different plants using the same system is as great as the difference between systems.

Platinum Contact Plants.—The essential steps in a platinum contact process are (1) burning sulfur or pyrites, (2) purification of the gas, (3) passing the gas over the catalyst, and (4) absorption in sulfuric acid of the sulfur trioxide so formed. The most difficult problem is to obtain a suitably purified gas to pass over the catalyst. Many substances such as dust, halogens, and metallic oxides, when present even in minute amounts, poison the platinum contact mass, greatly reducing the rate of reaction and making it necessary to replace the catalyst.

Figure 21 is a flow sheet of a somewhat idealized contact process plant. Gas from the burners (usually operated on sulfur) passes to coolers in which some dilute acid may be precipitated. It next goes to a scrubber where suspended matter is removed by weak sulfuric acid, and then through filters for final purification. The drips from coolers, scrubbers, and the filters are collected in the weak-acid tank to be recirculated. This acid is maintained at the desired concentration by adding water and overflowing weak acid. After the filters there is a second scrubber in which the gas is dried with 96 to 99 per cent sulfuric acid. This concentration is maintained by adding oleum. Somewhere in the system, but usually following this scrubber, is a blower which moves the gas through the system.

The gas must be heated to the initial reaction temperature before being brought into contact with the catalyst. In normal operation this heat is supplied by the heat of reaction through heat interchangers. The direct-fired preheater is provided for starting up and to compensate for occasional irregularities in operation. The exact arrangement of the heat exchangers, the converters, and their interconnecting piping, varies from plant to plant, but the arrangement shown is fairly typical. The gas first passes through both heat interchangers in order to heat it to the reaction temperature. It then passes through the first converter where, because of the high temperature, the reaction proceeds rapidly but the equilibrium will not correspond to the best conversion. Most of the sulfur trioxide is formed here. The resulting hot gas is sent through the second heat interchanger where its temperature is lowered. It then goes to the second converter which operates at a lower temperature than the first, and, therefore, completes the conversion under the most

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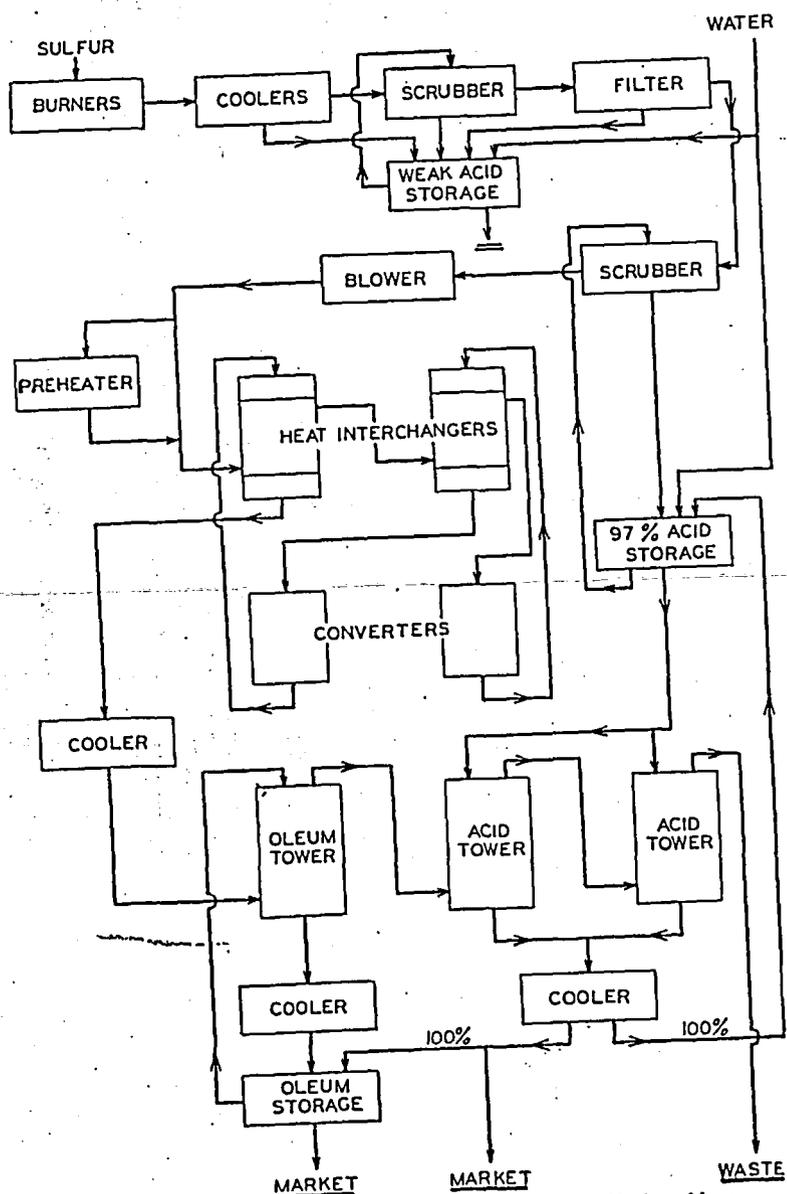


Fig. 21.—Flow sheet of contact process for sulfuric acid.

favorable equilibrium conditions, but at a slower reaction velocity. The gas then goes through the first heat interchanger where it is further cooled by the incoming stream of sulfur dioxide, and then to a final cooler. Here air or water bring the gas down to a moderate temperature. The stream of gas, which now contains nearly all of its sulfur as sulfur trioxide, goes to the oleum tower. This is fed at the top with acid stronger than 100 per cent, which absorbs sulfur trioxide to make still stronger oleum, leaves the tower through a cooler and goes to the oleum storage. Sufficient 97 to 98 per cent acid is added to this tank to give oleum of the desired final concentration, part of which is withdrawn for market and the rest circulated over the tower. The remaining gas, still containing some sulfur trioxide, goes to two acid towers, which are fed at the top with 97 per cent acid. These absorb the remainder of the sulfur trioxide, and are so regulated that they produce approximately 100 per cent acid, which passes through a cooler. Part of this acid is withdrawn for the market, and the rest goes to the storage tank, where sufficient 94 to 97 per cent acid or water is added to maintain its strength between 97 and 98 per cent. This system of towers is not followed in all plants. There may be more or less than three towers and the flow of acid through them may be more complicated than shown in this flow sheet. The absorbing system is varied according to the concentrations of acid to be marketed. It should also be noted that practically no two contact plants are identical, and this flow sheet must be considered as merely illustrative.

Burners and Gas Purification.—Burners for the contact process do not differ from those described on page 46, except that a few plants making high concentration oleum have the burners so arranged that the air supply can be dried with strong sulfuric acid. In any case the gas is cooled to about 120° F. by passing through a series of lead pipes, which may be submerged in water or sprayed with water on the outside.

Pyrites are not commonly used as the raw material in the contact process because of the impurities which they introduce into the gas. When pyrites are used, dust chambers are provided between the burners and the gas coolers; and the subsequent purification system is more extensive.

The next step in the process involves the further cooling of the gas, the further removal of suspended matter, and the elimination

of any halogens which may be present. All of these may be accomplished simultaneously by scrubbing with sulfuric acid, which ordinarily is not stronger than 55 per cent if halogens are to be removed. The simplest way of fulfilling these conditions is to use one or more packed towers over which the acid used as the scrubbing medium is circulated. If more than one tower is used, the operation is so adjusted that the acid in the last tower is nearly 98 per cent in order that the gas may be dry. It is not necessary that these towers operate strictly in countercurrent, since the concentration of moisture or halogens in scrubbing acid is kept very low. Consequently, the acid used in one tower is recirculated over that tower and only a fraction drawn off to the next tower in the series.

In order to remove the heat, the circulating acid may be cooled outside the tower in lead coils immersed in a tank of water; and in this case the amount of acid circulated must be large to keep down its average temperature in the tower. There might seem to be advantages in placing lead cooling coils in the tower itself, but the saving in acid circulation is offset by difficulties of construction. In some installations, however, the packing is completely replaced by closely spaced lead coils, through which cooling water circulates.

Although the scrubbing system gives nearly complete purification, it is necessary that the gas be absolutely free from suspended mist or solid particles. The usual way of removing these is by filtration. Various styles of filters have been used, but the most common one is a rectangular box of relatively large cross-section, lead lined, and filled with coke which has been carefully screened and washed. In a plant which makes 30 tons of acid per day the filter may be 30 to 40 feet wide, 50 to 60 feet long, and 15 feet deep. It should have a sloping bottom from which the acid which is collected may be drained. The coke should be graduated in size and may range from $\frac{1}{2}$ -inch lumps at the bottom to pieces as small as $\frac{1}{4}$ inch or even 10 mesh at the top. Small filter boxes packed with sawdust and asbestos fiber or mineral wool have also been used successfully.

The gas leaving the filter must be thoroughly dry. Unless 98 per cent acid was used in the scrubbing system, the final drying follows the filters and is usually done in a cast-iron tower, packed with quartz or stoneware shapes which are sprayed with 97 to 98 per cent acid.

Heat-transfer System.—After purification the gas is heated to the reaction temperature either by a direct-fired preheater or by heat interchangers. Since the gas is dry, these and subsequent units in the system may be made of steel. Cast iron is less suitable, as the graphite in it is acted on by hot sulfur trioxide. The heat interchangers are ordinary tubular heaters with steel shells and boiler tubes. The gas to be heated usually passes around the tubes. Baffles are placed inside the heater to prevent short circuiting, lengthen the gas path, and increase the rate of heat transfer. The gas which is supplying the heat passes inside the tubes and generally goes through all the tubes in parallel. The direct-fired preheater consists of a large number of boiler tubes connected in series and arranged in the flue of an oil or coke fire.

Converters and Catalysts.—The classification of contact plants is usually based on the type of catalyst mass. A process in which the platinum is supported on asbestos mats is called a *Badische process*, and a process in which the platinum is carried on granulated anhydrous magnesium sulfate, a *Grillo process*. These two are the ones principally used in the United States.

The converters consist of vertical, cylindrical steel shells with supports at intervals on the inside. In the *Badische process*, mats of loosely woven asbestos cloth are held in frames which rest on these supports. A mat is first dipped in solution of platinum chloride and is then carefully dried and ignited, taking particular care not to contaminate the mass with poisons. In the *Grillo system*, elaborately purified magnesium sulfate is dried and ignited, broken up, and the lumps carefully screened. These lumps are then moistened with a solution of platinum chloride and again ignited. This granular mass is loaded on perforated steel trays which fit into the converter shell. The average contact plant in the United States contains 14 to 16 troy ounces (370 to 500 grams) of platinum for each ton of daily output, calculated as 100 per cent sulfuric acid.

When the contact mass becomes poisoned, if the contamination is slight, the efficiency may sometimes be restored by merely raising the temperature of the incoming gas. Sometimes, if the poisoning is due to small amounts of arsenic, it may be overcome by filling the converter with chlorine. If the poisoning is serious, the catalyst must be reworked. This is quite simple in the case of the *Grillo mass*, as it merely involves dissolving

the mass with water and aqua regia and then drying and regranulating. With the Badische contact mass the asbestos fiber usually has become so brittle that it will not stand handling. The platinum must be dissolved and a new mat prepared.

Absorption Systems.—The oleum absorption towers are usually constructed of a sheet steel shell, lined with removable sections of cast iron or with acid-proof brick, and packed with quartz or stoneware shapes. The 100 per cent absorption towers are usually cast-iron towers similarly packed. The acid coolers both for oleum and for 100 per cent acid are made of cast-iron pipe, which carries the acid in the annular space between it and a smaller cast-iron pipe supplied with cooling water.

The absorption towers may be fed with acid of any strength over 97 per cent. If oleum is to be made, the gas will first pass through a tower fed with acid of 100 per cent or stronger. Such strong acids exert an appreciable vapor pressure of sulfur trioxide and, therefore, the absorption in such a tower will be incomplete. In order to insure recovery of the final traces of sulfur trioxide, a countercurrent system must be used, and the absorption completed in a tower fed with acid of 97 to 99 per cent so that the residual vapor pressure of sulfur trioxide in the absorbing liquid will be negligible.

Acids more dilute than 97 per cent cannot be used because they exert an appreciable, though low, vapor pressure of water. In the presence of free sulfur trioxide even minute concentrations of water vapor condense to form a mist of sulfuric acid which is very difficult to recover. If sulfur trioxide gas is to be absorbed, there is an appreciable difference in vapor pressure between the gas and liquid phase which causes it to diffuse to the surface of the absorbing liquid. If, on the other hand, instead of gaseous sulfur trioxide, finely divided liquid sulfuric acid is to be absorbed, there is no such potential difference tending to drive the particles to the surface of the absorbing liquid. The only way these particles may be removed is by causing them to settle or to impinge on a surface, but both of these are difficult in practice and mist formation must be avoided.

The absorption of sulfur trioxide is strongly exothermic. A rise in temperature of the absorbing acid in any of the towers is undesirable; for in the oleum towers this means an increase in the vapor pressure of sulfur trioxide with a consequent decrease

of capacity, and in the final towers it means an increase in the vapor pressure of water with a consequent tendency to mist formation. Coolers are therefore provided in the acid-circulating system of all towers.

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Problems

1. What is the composition of the gas obtained by burning pure FeS_2 with 50 per cent excess air, assuming that all the iron goes to Fe_2O_3 ?
2. A sulfuric-acid plant makes 100 tons of 60° acid per day. How many pans 3 by 6 feet will be needed to burn the sulfur? How many Glens Falls burners or how many Vesuvius burners, of what size, would do the same work?
3. Specify the size of the Glover tower for the plant of Problem 2. Assume an inlet gas temperature of 1000° F. and a gas velocity of 1.5 ft. per second based on the inlet gas volume.
4. Specify the size of the chambers for this plant.
5. How much water must be supplied to the chambers?
6. For your solution of Problem 4, specify the size of the Gay-Lussac tower.
7. Each of two plants makes 50 tons of 66° acid per day in a tower concentrator. One takes 60° acid from the Glover tower for concentration, the other finds it necessary to send chamber acid to the concentrator at 53° B_é. What is the saving in water rate in the first plant?

8. Two burner gases are obtained by the combustion of pure sulfur, one with 50 per cent and one with 100 per cent excess air. What will be the concentration of SO_2 in each at equilibrium at 450°C .? What will be the percentage conversion of SO_2 to SO_3 in each case?

9. A contact plant is to produce 10 tons of 20 per cent oleum and 40 tons of 98 per cent acid per day. The oleum tower is fed with 98 per cent acid. The 98 per cent tower is fed with 97 per cent acid obtained by diluting part of its output. Calculate the amount of acid fed to each tower.

MEMO

DATE: January 13, 1999
 TO: File
 FROM: Jeanette Stanley
 Environmental Chemist
 NC Superfund Section
 RE: VC Chemical -- Wadesboro
 Wadesboro, Anson Co., NC



On December 17, 1998, Serafino Franch, Environmental Chemist, and I visited the VC Chemical Wadesboro site. This site was originally recommended for investigation by Irene Williams, NC Superfund Section. We obtained a key to the gate from Al Scarborough at Scarborough Hardware. The property was posted and inaccessible by vehicle. Mr. Scarborough said he owned adjacent property and had found it necessary to restrict access due to trash dumping and wild parties. Mr. Scarborough said that the current property owner, Mr. Weston, had lived in the on-site house trailer at one time.

As we entered the property, we walked near the former lead acid chamber area (as indicated on the Sanborn maps) and noted the characteristic magenta-colored soil (indicating lead contamination) in the vicinity. We noticed that there were nearby residents and that one resident was in her yard. We walked to her yard and introduced ourselves. She gave us her name and address:

Mrs. William T. Wall
 Rt. 2 Box 9
 Wadesboro, NC 28170 (704) 694-3560

Mrs. Wall said that her husband was recovering from a recent stroke. She said that her neighbor, Reverend Leon Tyson was also recovering from a stroke. The other house close to the site was vacant at the time of our site visit, but Mrs. Wall said she anticipated that someone would be moving into the home. I called today and she said that the home was now rented and it appeared as if the residents were still moving. She did not know if the new residents have children. All three homes use groundwater wells for drinking. Mrs. Wall said that another neighbor closer to Stanback Ferry Road was named Robert "Patchie" Clark. She said that the three homes that were occupied during our site visit housed two residents each, all elderly couples. Mrs. Wall said that she did not know of anyone who ever entered the former fertilizer property. She had never been on the adjacent property. We noted a vegetable garden between the Wall home and the nearby vacant home. We then began our tour of the site, taking a number of photographs:

Photo #1	Looking north toward former acid chambers
Photo #2	Characteristic magenta-colored soil and sulfur. Area within 200' of garden and closest drinking water well.
Photo #3	Outfall of old terra cotta pipe, vacant residence in background
Photo #4	Note well house to left of house.
Photo #5	Acid Chamber area, looking west from yard of vacant home. Note corner of concrete wall.

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Photo #6 Small Brick buildings to the South of the former acid chambers building
Photo #7 Small Brick buildings to the South of the former acid chambers building
Photo #8 Small Brick buildings to the South of the former acid chambers building

We then walked up the berm on the east side of the facility and found that the facility included a concrete wall that had been constructed to support a two-story- high bank of dirt which supported a former railroad track. Photo #9 was taken looking west from the top of the berm toward the edge of wall. We then walked down the northern end of the berm and toward center of the property. We noted a vacant, uninhabitable house trailer, Photo #10. We then walked to the front of the trailer and photographed the old reservoir and water tank in background (Photos #11 & 12). A well was noted about 15' northwest of the reservoir. The well had a short concrete culvert as housing with no top. (During a telephone conversation, Mr. Weston said that he had used this well for drinking when he lived on the property.) There was no visible tap or labeling on the well. Proceeding northward along the western perimeter of the former facility, we noted a white, granular substance that looked like old fertilizer (Photos #13 & #1 (roll 2)) filling the former railroad bed.

The area was very thick with briars and undergrowth. We found an opening and, in a northeasterly direction, crossed over the concrete pad of the former dump shed and fertilizer mixing building. Small trees and other vegetation were growing in the cracks of the pad throughout. There was standing water in some areas of the pad. There were signs of past "recreational use" of the property such as beer cans, but no signs of recent use.

Photo #2 (roll 2) was taken from the rear of the former building, standing in the former road bed and looking south toward the degraded pad. Photo #3 (roll 2) was taken of the ditch draining the rear (north) of the building. Photos #4, #5 & #6 (roll 2) were taken of the former railroad bed and loading platform at the northwest corner of the facility. Proceeding along the western perimeter of the property, we attempted to locate a surface water outfall. Serafino located a culvert under the former railroad bed and the outfall into the unnamed tributary (UT) to Brush Fork. Photos #7 & #8 (roll 2) were taken of the stream the receives the overland flow from the northern half of the property.

We had then essentially circled the property. We located the magenta-colored soil again (Photo #9 (roll 2)), and then followed the overland pathway from this area of soil. We noted a large dog running loose and decided to return to the vehicle and attempt to locate the PPE for the southern half of the property from the vehicle. We determined that there were no additional culverts under the former railroad bed on the north side of Stanback Ferry Road. The overland pathway follows a ditch to the west of the nearby homes and to the east of the former railroad bed and then enters a culvert under the road. On the south side of Stanback Ferry Road, the overland pathway follows a low area along the perimeter of a residential property and then enters a flowing stream at the rear of the home. This stream flows in a westerly direction, through a culvert under the former railroad bed and into the UT to Brush Fork.

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While investigating the overland pathway, we noted a "backyard garage" facility that was operating and an additional home on the north side of Stanback Ferry Road not discussed by Mrs. Wall, making a total of five homes and a garage on the north side of Stanback Ferry Road. The one home on the south side of Stanback Ferry home near the site would makes a total of six homes, three homes within 200' of the facility and another three homes and a garage in close proximity to the overland pathway and downgradient from the site. All homes use wells for drinking.

I called Mrs. Wall today and she said that one of the two homes close to Stanback Ferry Road on the north side is unoccupied. The other home is occupied by Mr. and Mrs. Robert Clark. The brick home on the south side of Stanback Ferry Road is occupied by "Boot" Clark, a relative of Mr. Robert Clark's. Mrs. Wall said that Mr. Robert Clark operates the garage.

Memorandum

DATE: June 1, 1999

TO: File

FROM: Scott C. Ryals 
Environmental Chemist
NC Superfund Section

SUBJECT: Site Investigation Reconnaissance (May 27, 1999)

Virginia Carolina Chemical Company (VCC Company)
Wadesboro, Anson County, NC
EPA ID: NCD TBA

On Thursday, May 27, 1999, Mr. Scott Ryals and Ms. Jeanette Stanley of the North Carolina Division of Waste Management SuperFund Section, conducted a site reconnaissance of the former VCC Company site in Wadesboro, North Carolina.

Upon arrival in Wadesboro, we stopped to acquire a copy of the City of Wadesboro public water lines from Mr. Hugh James. Mr. James informed us that to the best of his knowledge that the creeks alongside the property were not used for fishing. After leaving Mr. James, we stopped at Scarborough Hardware to inform Mr. Scarborough (a citizen who owns land in the area and acts as the contact person for access to the property) that we were going to be on the site and if he still had the key for the gate to the property. He informed us that the gate had been changed to a reinforced steel access gate due to people breaking into the property for the purposes of dumping refuse and illegal narcotics activities. Unfortunately, he also informed us that someone had run into the new gate in an effort to force it open and had damaged it so severely that it no longer functioned. Mr. Scarborough again expressed Mr. Weston's concerns as to the structural stability of some of the remaining buildings and of the possibility of uncovered elevator shafts and/or wells.

On arriving at the entrance to the site, we noticed that the gate had been hit and rendered unusable. We proceeded down an adjacent dirt road on which five houses that border the facility are located. Ms. Stanley and myself talked with each of the residents (list in the following table) and received verbal permission to return to sample their drinking water wells. None of the residents indicated that their water tasted or smelled out of the ordinary. Mr. Leon Tyson reported that his water was hard and that he had at one time used a treatment system, but the system had been removed. See attached aerial site map for the location of the houses. None of the houses are on city water.

Residences and Wells

Name	Address Wadesboro 28170	Phone # (704)	Number in Home / Children	WellheadAccess
1 Leon Tyson	Rt 2 Box 10	694-3805	2 / 0	Y
2 William Tyson	Rt 2 Box 9		2 / 0	Y
3 Bunyon Tyson	Rt 2 Box 9		4 / 2 (1yr & 6yr)	Y
4 Robert Clark	Rt 2 Box 8	694-3943	2 / 0	Y
5 Lucinda Maske	Rt 2 Box 8	no phone	3 / 1 (pregnant)	On Clark Well
6 Robert James				N

After talking with the residents, we proceeded through the underbrush that has grown up around the facility. Several pictures (see attached photos) were taken of the remaining buildings, the elevated RR track bed, the fire water pond and nearby well, a large separator and what looked to be a bagging room with a large roller conveyor line. Within this room, there was evidence of smelting activities (small kiln and two molten metal transfer buckets, what appeared to be metal (lead) slag on the floor and ceramic molds).

Because of the possibility that phosphate ore contains naturally occurring Radon 225, a radiation survey was conducted. The highest radioactive readings were observed near the separator tower. The readings were taken on a Micro R Meter, Model 19 manufactured by Ludlum Measurements, Inc. of Sweetwater, Texas. The off-site background reading was 5 micro R/hr. Near the stained soil outflow from the lead-acid chambers and around the general site except as mentioned, the reading was 15 - 18 micro R/hr. The open area between the abandoned trailer and the separator was 40 micro R/hr. and immediately near the separator the readings increased to 110 micro R/hr.

There was no evidence of any uncovered wells or elevator shafts as indicated by Mr. Scarborough. The entire site was densely overgrown with grasses, small to medium pines and hardwoods and briars.

We proceeded to locate the two probable points of entry (PPE) to the surface water from the site. The outflow pipe leading from the lead-acid chambers empties along the old railroad bed. The old RR bed leads in a southerly direction. The pathway flows under Stanback Ferry Road, crosses the Robert James property and turns sharply to the West and enters an un-named tributary (UT) to Brush Creek, the PPE. The second PPE was located north of the fire pond. There was a lined channel that seemed to follow the remaining foundation of the concrete pad. The channel and a pipe which lead from somewhere under the pad, lead to a natural channel which feeds into a flowing stream. The use of this lined channel is unclear, but the best estimate would be for storm water management off the roof of the structure that once existed. Both PPEs fed into an UT which feeds into Brush Creek. After walking the length of the 2 PPE, the creeks did not indicate the presence or capability of supporting fish. There were several deer tracks and one turtle observed during the reconnaissance.

Before leaving Wadesboro, Ms. Stanley and myself stopped in the local public library to try to find some pictures or other history concerning the operations at the VCC Co. site. We were not able to find any picture, but did manage to find a reference which indicated that the plant opened

in 1911 (See attached reference). We then searched the library copies of the local paper that was published in 1911, but there was no reference to the plant. We then proceeded to the local paper which has been in business since the turn of the century with the hope that they would have a site picture. Unfortunately, the paper did not have a computer index and we did not have the time available to search through the back issues of the paper.

Left office @ 8:15 am w/
Jeanette Stanley de Candant
a SI Record of the former
WCC site in Wachsboro, NC.

Arrived Wachsboro City
Hall @ 11:30 am to
meet w/ Mr. Hugh James
to acquire a map of
the city H₂O lines.

→ Jean Tyoro 694-3803

→ Rt 2 Box 10
Wachsboro, NC

H₂O is slightly hard
(2 people in house)

William ^{Tyoro} living next door. Box 9

Bennyon - wife & 2 kids
29 yr. 1 yr / 6 yr

→ family only here 4-5 months.

Steve Gub

285

- Robert Clark, Zim
household

RT 2 Box 8

694 - 3943

Clark, Thomas

RT 2 Box 8

694 -

Laurinda Alaska

RT 2 Box 8

694 -

widow, husband, 1 yr.

on the way.

same as Mr. Clark.

Scott Lytle

385

A new Geo. & NC
by Bill Sharpe
Vol III - 26 Counties
Sharpe Pub. Co.
Raleigh, NC 1961.
Copied one pg. @ 15¢

After speaking w/ the
property owner occupying
homes adjacent to the
VCC site Jeanette and I
walked the property.

I took several pictures of
the remaining buildings
including the fire
shed & mixing shed.

Scott Lytle

photo listing:

Photo	Roll	Description
1	1	one of the edges on-site
2	1	interior of bldg.
3	1	Another Bldg on-site
4	1	retaining wall ^{about} _{to} _{top}
5	1	on-site reservoir
6	1	well head, to left of picture #5
7	1	Tower of Bldg to left of picture #5
8	1	Tower
9	1	Distribution network tower
10	1	retaining wall behind tower
11	1	reservoir in tunnel ^{outside} _{of} _{the} _{bl} _{dg}
12	1	Long shaker outside bldg #7
13	2	Small furnace w/ metal slag +
14	2	Another PPE
15	2	Another PPE into surface

* The building was the bagging house for the portland plant. Inside was found metal slag, typing units for molten metal area

Scott Lyde

Numerous carts for various items. This seems to be left over from Mr. Weston's attempt to produce metal castings at the site. His business was not successful.

for complete description, see S-1 Recon memo data 5/29/99.

Scott Lyde

NORTH CAROLINA DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES
DIVISION OF WASTE MANAGEMENT



June 29, 1999

JAMES B. HUNT JR.
GOVERNOR

Ms. Jennifer Wendel
NC Site Management Section
US EPA Region IV Waste Division
61 Forsythe Street, 11th Floor
Atlanta, Georgia 30303

WAYNE McDEVITT
SECRETARY

Subject: Virginia Carolina Chemical Company
Wadesboro, Anson County, NC
NCS FN0 406 924
Combined PA/SI Sampling
Date: July 15-16, 1999

WILLIAM L. MEYER
DIRECTOR

Dear Ms. Wendel:

The following is a summary of proposed PA/SI sampling at the former Virginia Carolina Chemical Company (VCC) site on Stanback Ferry Road in Wadesboro, Anson County, NC. This sampling plan is based on PA research in progress, on-site and off-site reconnaissance and a historical investigation of the processes used at this site and others operated by the same company within NC by the NC Division of Solid Waste Superfund Section.

Site Background:

The VCC site is located approximately 1/2 miles west of the town of Wadesboro, NC on Stanback Ferry Road in Anson County, NC. The site was a former fertilizer manufacturing facility that operated from 1911 through the end of World War II and occupies approximately 10.38 acres of land (See figure 1). The site remained inactive until it was purchased from the county in action by Mr. Carl Weston in 1980. Mr. Weston did not develop the site. The land is heavily overgrown and surrounded by woodlands, few of the original structures remain (See Figure 2) and apart from the gate on the access road, there are no access controls at the site.

Based on investigations at other fertilizer manufacturing facilities throughout NC, the potential contaminants include lead (Pb) from the large lead lined acid mixing chambers, other metal contaminants from the pyrite and phosphate ores used in the production of the fertilizer, potential chlorinated and phosphate fertilizers manufactured on-site and nutrients (sulfates and nitrates).

Groundwater Pathway:

The site is located in a rural area surrounded by woodlands and small agricultural fields. There are three residences served by drinking water wells that are adjacent to the property and three additional residences and a small auto repair business that lie down gradient from and in close proximity to the overland flow pathway. All residences are within a ¼ mile of the facility. According to both county and city officials, there are no water lines serving these residences. The city public water supply, which serves approximately 3,800 people, is not threatened by the site. Table 1 lists the groundwater samples to be collected. Samples will be collected at each well for metals, volatiles, semi-volatiles and nutrients.

Table 1: VCC Wadesboro Groundwater Sampling Locations

Sample Number	Location	Analytes	Comments
VCC-01-PW, N	Figure 2	Metals, V, SV, N	Private well
VCC-02-PW, N	Figure 2	Metals, V, SV, N	Private well
VCC-03-PW, N	Figure 2	Metals, V, SV, N	Private well closest to lead stained soil.
VCC-04-PW, N	Figure 2	Metals, V, SV, N	Not shown on figure, but there is a small business and home. Shares well with #5.
VCC-05-PW, N	Figure 2	Metals, V, SV, N	Private well directly across Stanback Ferry Rd from #5.
VCC-06-PW, N	Figure 2	Metals, V, SV, N	To be Determined, Bkgd
Trip Blank	Figure 2	V, N	Organic QA/QC
Pre-Preservative Blk	Figure 2	Metals	Inorganic QA/QC
Post-Preservative Blk	Figure 2	Metals	Inorganic QA/QC

PW = Groundwater Well

V = Volatile organic compounds

SV = Semi-volatile organic compounds

N = Nutrients

Soil / Source Exposure Pathways:

Based on our on-site reconnaissance and limited operational history of the site, six potential source areas have been identified for sampling. These include a large area of magenta stained soils that are believed to be from the lead-lined acid mixing chambers, an area of soil from a former pole treatment and storage facility, soil from the pyrite and phosphate storage area, soil from the acid mixing area, soil from the fertilizer mixing and bagging operations area and a surface water sample from the on-site water reservoir. There is evidence that the nearby area has been used for clandestine gatherings and potentially as a recreational area for the nearby children. Table 2 lists the soil / source samples to be collected.

Table 2: VCC Wadesboro Soil / Source Area Sampling Locations

Sample Number	Location	Analytes	Comments
VCC-01-SL	See Figure 2	Metals, V, SV, N	Background #1
VCC-02-SL	See Figure 2	Metals, V, SV, N	Source 1. Stained soil source, composite sample
VCC-03-SL	See Figure 2	Metals, V, SV, N	Background #2
VCC-04-SL	See Figure 2	Metals, V, SV, N	Source 2. Near auto repair shop
VCC-05-SL	See Figure 2	Metals, V, SV, N	Overland flow southern PPE
VCC-06-SL	See Figure 2	Metals, V, SV, N	Source 3. Pyrite storage area
VCC-07-SL	See Figure 2	Metals, V, SV, N	Source 4. Acid-mixing area
VCC-08-SL	See Figure 2	Metals, V, SV, N	Source 5. Fertilizer mixing area
VCC-09-SW	See Figure 2	Metals, V, SV, N	Source 6. On-site reservoir

V = Volatile organic compounds
SV = Semi-volatile organic compounds
N = Nutrients
SL = Soil

Surface Water Pathway:

There are two probable points of entry (PPE) to the surface water at two points in an unnamed tributary to Brush Fork. The northern PPE (PPE 1 on Figure 3) is approximately 100 feet west of the site. The southern PPE (PPE 2 on Figure 3) that receives runoff from the potentially contaminated soil area is approximately 750 feet south of the site. The wetland inventory map shows the nearest wetland to be located approximately 1.5 miles downstream of the southern PPE; however, vegetation observed during the site visit and the topography of the area adjacent to the stream bed approximately 100 feet below the southern PPE indicates the potential for a wetland area much closer to the site. Table 3 lists the sediment and surface water samples to be collected.

Table 3: VCC Wadesboro Surface Water and Sediment Sampling Locations

Sample Number	Location	Analytes	Comments
VCC-01-SD, SW	See Figure 2	Metals, V, SV	Background, northern PPE
VCC-02-SD, SW	See Figure 2	Metals, V, SV	Northern PPE
VCC-03-SD, SW	See Figure 2	Metals, V, SV	Upstream of roadbed, below northern PPE
VCC-04-SD, SW	See Figure 2	Metals, V, SV	Background of southern PPE
VCC-05-SD, SW	See Figure 2	Metals, V, SV	Southern PPE
VCC-06-SD, SW	See Figure 2	Metals, V, SV	Upstream of roadbed, above southern PPE
VCC-07-SD, SW	See Figure 2	Metals, V, SV	Downstream of roadbed, above southern PPE
VCC-08-SD, SW	See Figure 2	Metals, V, SV	Background of creek between residences and site
VCC-09-SD, SW	See Figure 2	Metals, V, SV	Creek between residences and site

V = Volatile organic compounds
SV = Semi-volatile organic compounds
N = Nutrients
SD = Surface Sediment
SW = Surface Water

Please feel free to contact me at (919) 733-2801 ext. 316 or ryalssc@wastenot.enr.state.nc.us if you have any questions.

Thank you.



Scott C. Ryals
Environmental Chemist / Toxicologist
NC Superfund

Attachments

cc: File

Approved: _____

Jennifer Wendel
NC Site Management Section

Date: _____

110 02
LANDFILL

147200-11

MEMPHIS 25 MI
POLKTON 4.5 MI

1470

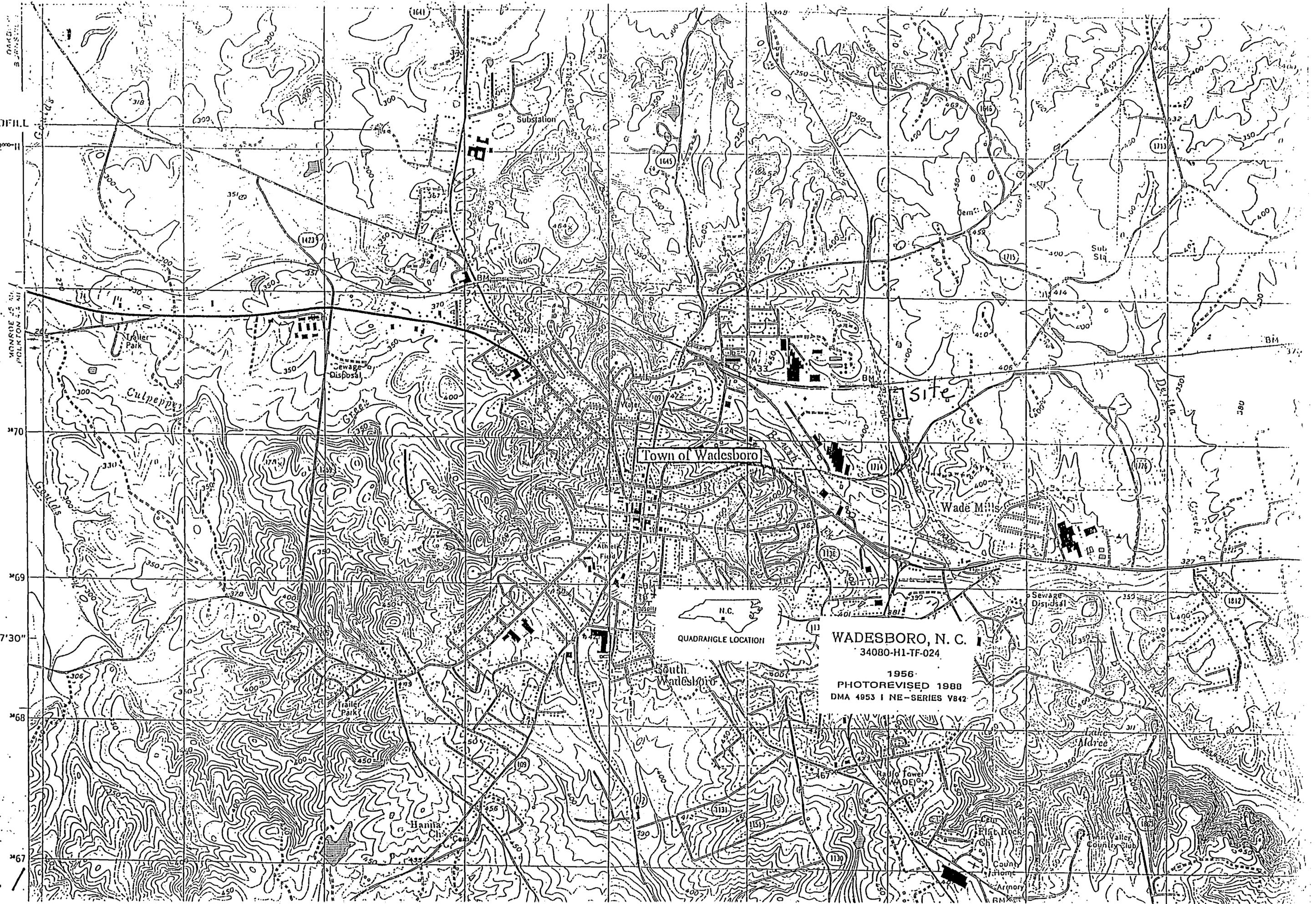
1469

5730"

1468

1467

Figure 1



Town of Wadeboro

site

N.C.
QUADRANGLE LOCATION

WADESBORO, N. C.
34080-H1-TF-024

1956
PHOTOREVISED 1988
DMA 4953 I NE-SERIES V842

South Wadeboro

Sewage Disposal

Lake Aldree

Flat Rock

County Home

Armory

Valley County Club

County Home

Armory

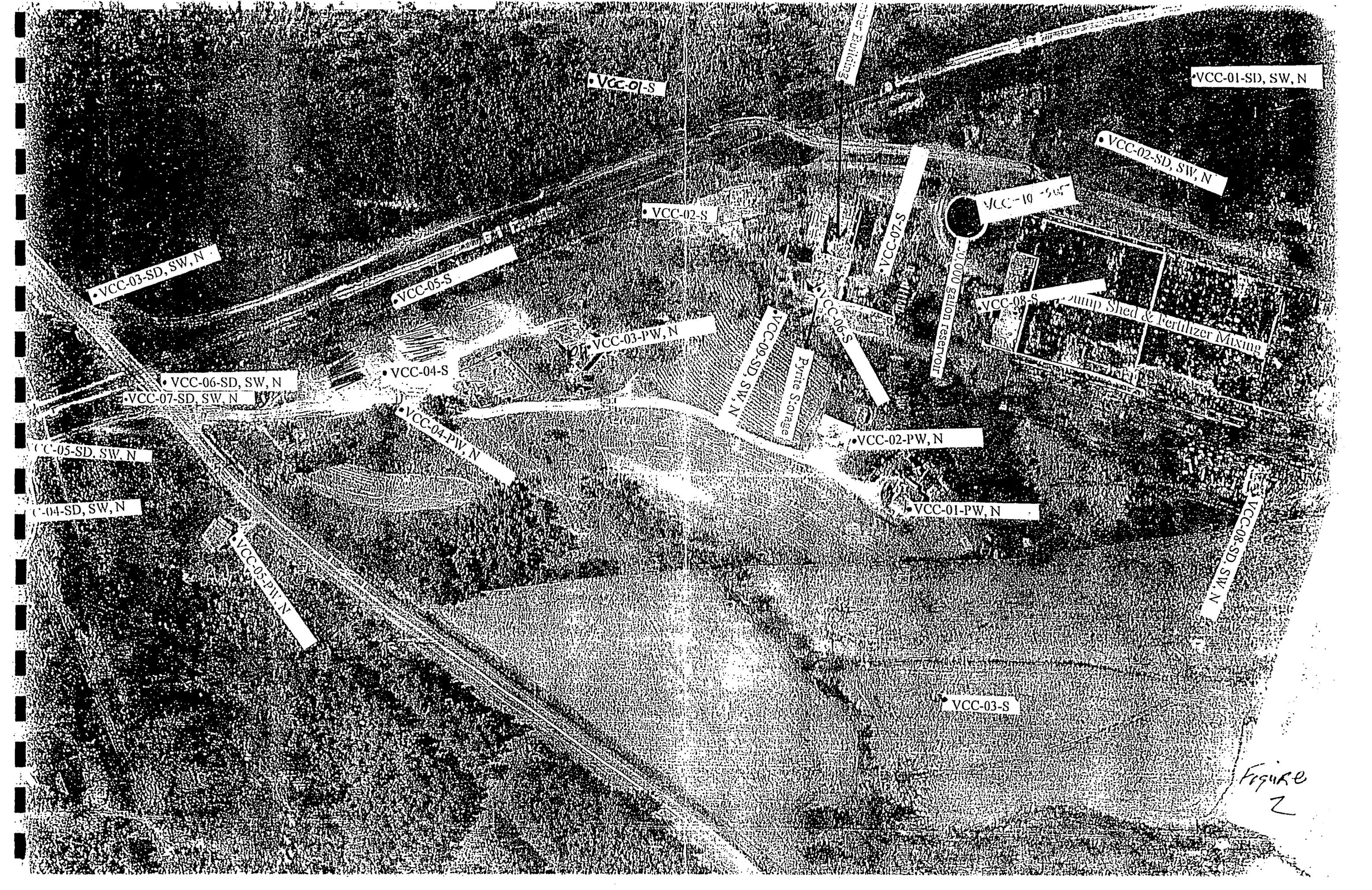


Figure
2

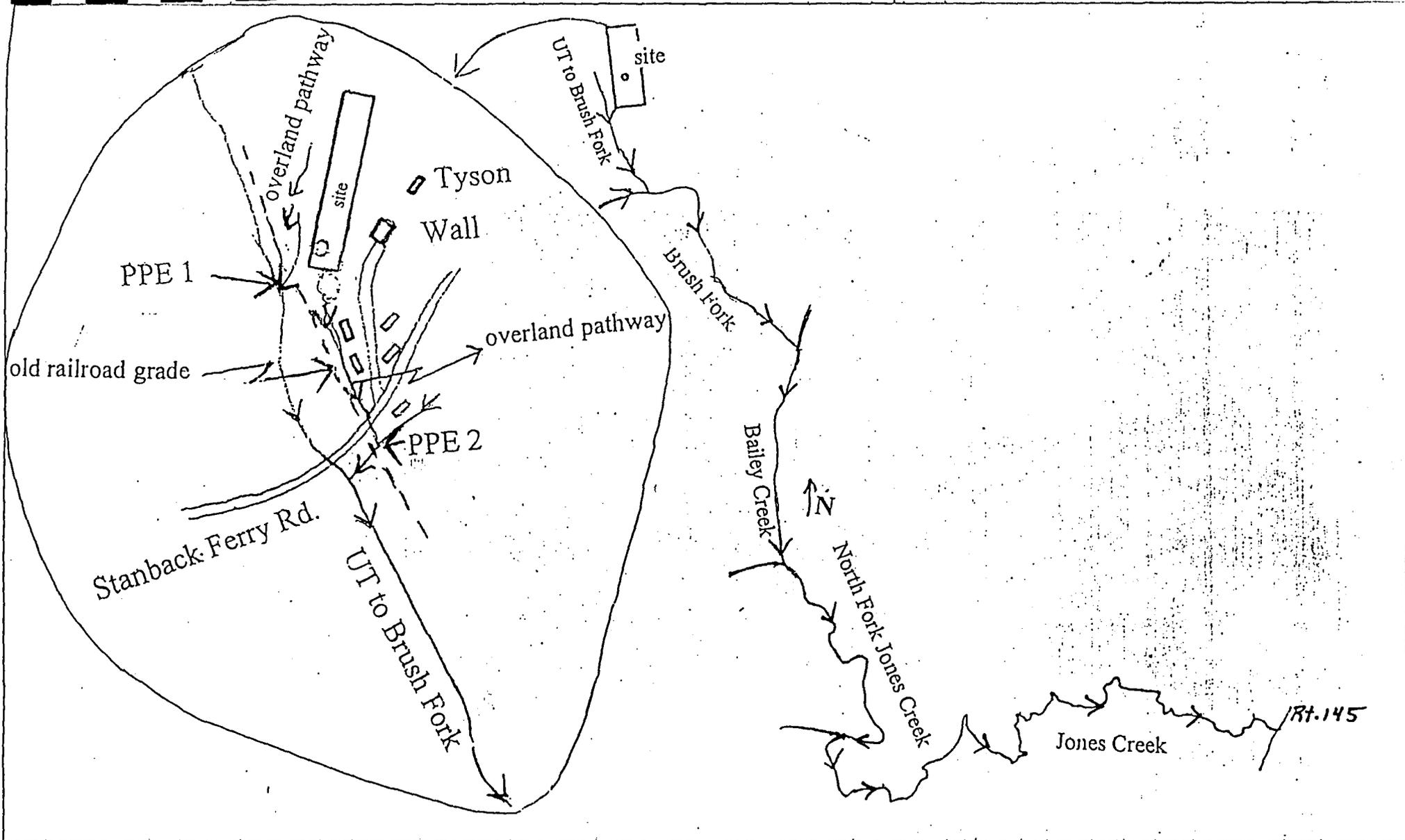


Fig. No: 3	Title: Surface Water Pathway		
North Carolina Division of Waste Management Superfund Section	Scale:	Date: September 1998	Drawn By: J. Stanley
	Site Name: VCC --- Wadesboro		NCD

United States Environmental Protection Agency



Region IV
61 Forsyth Street
Atlanta, GA 30303



Ref. 10

Facsimile Cover Sheet

TO: Scott Ryals-NCDENR

FAX No: 919-733-4811

From: Jennifer Wendel-U.S. EPA

Office phone: (404)-562-8799
FAX: (404)-562-8788

Office code: 11th fl

Date: July 7, 1999

Number of pages,
including cover:

2

MESSAGE: Approval page for VC Chem/Wadesboro sample plan

919 956-4410

Please feel free to contact me at (919) 733-2801 ext. 316 or ryalssc@wastenot.enr.state.nc.us if you have any questions.

Thank you.

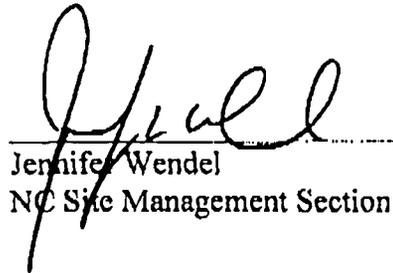


Scott C. Ryals
Environmental Chemist / Toxicologist
NC Superfund

Attachments

cc: File

Approved:



Jennifer Wendel
NC Site Management Section

Date: 7/6/99

7/26/99

VC Chemical Wastewater

Doug Rumbold

Jeanette Stanley

Scott Ryals

Jim Barker

Henry Zinn

Arrived site ~ 10:30.

Divided equipment +
Selected sample locations

Sample Location, VCC-07-SW

down gradient / downstream

of confluence of 2 streams

~ 40 - 50' downstream

of confluence

water collected 1117 am

SW ~ 1120 am

07-SD 1120

Sediment - light brown, sandy

Summit + talus mixed & collected

Located 04-SW/SD
behind shed of Bob Clarke
home in stream flowing
westward toward PPE of
Background of southern PPE.

water collected 1155

Sediment " 1200

sediment - silty sand -
~130' up gradient from
PPE

Located 05 SW/SD (PPE)
~10' west of culvert
under road / old Railroad
bed

(1220)

Sediment silty

Went to site to photograph
Sampling & Facility

Arrived VC-03-SW
1320

1327 Jeanette S. Collects surface
water VOC, SVOC, & metals at
location 03 in stream \approx 50 ft
upstream of Starbuck Ferry Rd

1335 Jeanette S. Collects Sediment
Sample VC-003-S0 from same
location - Sandy sediment.
VOC, SVOC, metals

1445 Jeanette S. Collects Soil
Sample VC-006-S1 from Ditch
along R.R. Tracks \approx 55 feet
upgradient of Starbuck Ferry Rd. -
Ditch was Dry.

Removed \approx 6" organic matter &
6" soil. Collected sample at
11. Soil was loamy w/ some red clay

1515 - began purging Tyson well

VC-01-PW; Cal. grate #I70423

pH meter to 9.91 in pH 10 & 6.98 in pH 7

1530 pH 6.90 @ 20°C

Turb. 0.94

Cond. 473 μ S

1535 collected sample

⁹⁸
1550 - began purging Wells well
VC-02-PW

1535	pH	Temp	Cond	Turb
	6.35	25.4	1.89	1.19
			5.2 mS	

<u>1600</u>				2.10
	6.34	24.9	5.9 mS	

1605	6.52	23.8	5.63 ms	3.15
------	------	------	---------	------

Sevette S Collects Drinking water Sample VC-002-PW for VOC, SVOC, metals & Nutrients. Sample collected at well house tap.

BK well
ORR Burr
Stambaek Ferry Rd
P.O. Box 1045
Wadesboro 28770
1C-06-PW

began purging 1635
Burr Construction
(704) 694-4289

pH	temp	Cond	turb	time
6.90	22.7	2.77ms	0.64ntu	1640
6.92	20.6	2.61ms	0.56ntu	1645
6.88	21.2	2.16ms	0.29ntu	1650

Collected sample 1650 — Seawette S.
VOC, subc, metals, Nutrients
sample collected from well house tap

Returned to Clark well, acidified,
left site ~ 1730

200 27

7-26-99

200 27

7-26-99

Sample #	Locality	Collection Team	Collection Time
VCC-01	PW M, V SV, N	2	15:35
VCC-02	PW M, V SV, N	2	16:05
VCC-03	PW M, V SV, N	1	16:00
VCC-04	PW M, V SV, N	1	16:46
VCC-05	PW M, V SV, N	1	17:13
VCC-06	PW M, V SV, N	2	16:50
VCC-01	SL M, V SV, N	1	12:20
VCC-02	SL M, V SV, N	1	1:05
✓ VCC-03	SL M, V SV, N	1	15:25
VCC-04	SL M, V SV, N	1	15:45
VCC-05	SL M, V SV, N	1	15:15
VCC-06	SL M, V SV, N	1	1:18
VCC-07	SL M, V SV, N		
VCC-08	SL M, V SV, N	1	12:40
VCC-09	SL M, V SV		
Post-transitive	M		

Scott Rybe

Collection Date	Duplicates Taken	Total Samples @ Site
7/26	N	4
7/26	N	4
7-26-99	Y	8
7-26-99	-	4
7-26-99	-	4
7/26/99	N	4
7-26-99	-	4 ⁵ 3
7-26-99	Y	8 6
7-26-99	-	4
7-26-99	-	4 3
7-26-99	-	4
7-26-99	-	4 3
7-26-99	-	4
7-26-99	-	4 3
7-26-99	-	3
		1

Scott Rybe

7-28

7-26-99

7-26-99

7-26-99

Sample #	Analytics	Collection Team	Collection Time
VCC-01 SW	M V SV	1	11:35
VCC-02 SW	M V SV	1	11:50
VCC-03 SW	M V SV	2	13:20
VCC-04 SW	M V SV	2	12:00
VCC-05 SW	M V SV	2	12:20
VCC-06 SW	M V SV		
VCC-07 SW	M V SV	2	11:20
VCC-08 SW	M V SV		
VCC-09 SW	M V SV		
VCC-01 SD	M V SV	1	11:35
VCC-02 SD	M V SV	1	11:50
VCC-03 SD	M V SV	2	13:35
VCC-04 SD	M V SV	2	12:00
VCC-05 SD	M V SV	2	12:20
VCC-06 SD	M V SV	2	14:45
VCC-07 SD	M V SV	2	11:20
VCC-08 SD	M V SV		
VCC-09 SD	M V SV		
V			

Scott Ryals

Collection Date	Replicate Taken	Total Samples @ Site
7-26-99	—	3
7-26-99	—	3
7/26	N	3
7/26-99	N	3
7-26-99	N	3
7-26/99		3
		3
7-26-99	—	3
7-26-99	—	3
7/26-99	N	3
7/26/99	N	3
		3
		3
		3

Scott Ryals

Eq 38

7/26/89

Photos

Roll 1

photo

- 1 TEST: Setup
- 2 N. PPE Backyard SW/SW
- 3 N. PPE collection
- 4 Bkgd soil
- 5 On-site soil between house & pond channels
- 6 Some soil
- 7 Some area
- 8 Pypite Storage
- 9 Pale Storage soil
- 10 pale storage runoff
- 11
- 12 Area 3

Roll 2

- 1 P W 2
- 2 P W 1
- 3 P W 4
- 4 P W 5
- 5 S. PPE Overland flow
- 6 S. PPE
- 7 Jim Asidpuy, ME²¹

Start by abe

7 of 38

7/26/89

- N. PPE Bkgd: Soil, Lt Brown & Sandy.
 - Coarser, Lt cloudy
 - Sample collected @ bank side, as great w/ in situ homogenized soils. Collected by JB.

- N. PPE Clean runny water! Soil. Lt. brown sandy w/ small gravel. Sample collected as great from bank. Collected by JB.

- Bkgd soil taken ~ 100' from access rd. Area covered by a pine forest. Soil Tan & Sandy.

- On-site soil ~ 6" deep & collection.
 4" med. grey sandy gravel
 4-7" reddish brown silty clay

Scan 7" purple soil.

8 of 38

7/26/99

- Re-site storage area
 Soil sample # 3
 thin gravelly layer
 above so. sub.
 Collected @ HT.

- pole storage area
 Soil # 4. The
 old garage has since
 burned. Had to move
 site up gradient of
 fire #20 for garage.
 Soil: silty sand w/
 gravel.

- Soil sample # 5
 represents potential
 runoff from former
 pole yard. Due to
 large amounts of detritus
 sample was taken on
 side of bank.

Scrub

9 of 38

7/26/99

Started surging SW 3
 @ 15:45.

PH	Turb.	Cond.	Temp °F
5 | 7.62	15.80	404 5800	19.6 °C
10 | 7.49	5.20	425	18.3
15 | 7.50	3.70	422	18.3

PH 4: surge @ 16:30

Time	pH	Turb	Cond.	Temp
16:35	7.45	6.6	327	19.9
16:40	7.32	4.7	317	18.9
16:45	7.25	5.5	322	18.7

Collected @ 16:46

Sample taken from
 -apert on house.

Scrub

10 of 31

7-26-99

PLW 5

Start 16:52

Time	pH	Temp	Turb	Conc.
15:00				
15:05				
15:10				
9K 7-26-99				
17:00	7.41	22.7	2.0	502
17:05	7.43	20.2	0.3	495
17:10	7.40	19.4	0.2	494
Cecilia 17:13				
Koc 2				
photo				
8	Checking pH.			
9				
10				
11				
12				
Left site @ 17:21!				
Arrived home @ 20:30				
John Gale				

11 of 38

7-28-99

On 7-27-99, Jenette
 Stanley & I spent
 8 hrs. preparing the labels
 for the samples & then
 preparing the samples for
 shipment to the NC
 Public Health Lab.

The trip kit (VFA) used
 2 VFA bottles that had
 been taken into the
 field but the H₂O
 was collected @ the
 lab on the 27th.

The following pages are
 the sample labels
 used.

* Jenette's notes are in
 site file.

Scott Gale

NORTH CAROLINA DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES
DIVISION OF WASTE MANAGEMENT



October 22, 1999

JAMES B. HUNT JR.
GOVERNOR

WAYNE MCDEVITT
SECRETARY

WILLIAM L. MEYER
DIRECTOR

Mr. Myron D. Lair, Chief
Emergency Response and Removal Branch
US EPA Region IV Waste Division
61 Forsyth Street, 11th Floor
Atlanta, Georgia 30303

Subject: Immediate Removal Evaluation Request
V.C. Chemical – Wadesboro (VCC)
NCSFN 0406 924
Wadesboro, Anson County, NC

Dear Mr. Lair:

The NC Superfund Section requests that the EPA evaluate V.C. Chemical – Wadesboro site for a possible removal action. The site is located approximately ¼ mile off highway 74, on Stanback Ferry Road in Wadesboro, Anson County, NC (Attachment 1). The site is comprised of approximately 10.38 acres of woodlands. There are several remaining buildings in various stages of decay. The most pronounced feature is the fire pond. The geographic coordinates of the site are 34° 58' 22" north latitude by 80° 03' 26" west longitude (Attachment 2) as measured from the fire pond. The area is mixed commercial/residential.

Mr. Carl Weston (903-813-1950) currently owns the site. This site was formerly owned by the Virginia Carolina Chemical Company (1908 to 1945) who operated a fertilizer manufacturing facility utilizing lead-lined, acid chambers. An operational history of the site from 1945 to the time that Mr. Weston purchased the site at auction from Anson County in early 1980 is not available at this time. The site has been abandoned for approximately 10 years.

The site was discovered by Ms. Irene Williams of the NC Superfund Section during a routine site investigation of another property previously owned and operated by the V.C. Chemical Company. Analysis of the magenta colored soils found at that site indicated the presence of elevated lead and arsenic levels. Further investigation lead to the discovery that the lead in the soils was due to the processes used to make super-phosphate fertilizers utilizing lead-lined, acid chambers. On May 26, 1999, NC Superfund conducted a site inspection of the Wadesboro site and discovered the same magenta colored soils. On July 26, 1999, NC Superfund conducted a combined

Mr. Lair
October 22, 1999
Page 2 of 3

PA/SI sampling trip in which surface soil samples were collected from an area of discolored soil, absent of vegetation, approximately 20 feet wide by 60 feet long. The results of the sample analysis (Attachment 3) revealed elevated concentrations of lead (3361 mg/kg), arsenic (92 mg/kg) and copper (1042 mg/kg).

The site investigation indicated that the area adjacent to the magenta colored soils was being used as a dump. Local citizens who own the adjoining property have complained about the teenagers and others who were "visiting" the area during the night. The adjoining property owners erected a gate across the access road to prevent access, but it was quickly torn down. Also adjoining the site are three residences. The residence closest to the site, within 250 feet, has two small children (one and six years of age) and the mother is expecting. There are no barriers between the site and the residences and the magenta soils are visible from the closest residence.

City and County water lines do not service this area. Sampling analysis of the potable wells did not indicate the presence of any elevated metals or other compounds.

Due to the high levels of lead and arsenic detected in the surface soils at the site, the proximity of the site to neighboring homes and the evidence of public access to the site, the NC Superfund Section requests that EPA evaluate the V.C. Chemical - Wadesboro site for a removal action.

State funds for this removal are not available at this time. Please let us know if and when a field evaluation can be conducted so we may coordinate your site visit with our staff. Please feel free to contact me at (919) 733-2801 ext. 290 or Dan.LaMontagne@ncmail.net if you have any questions.

Sincerely,



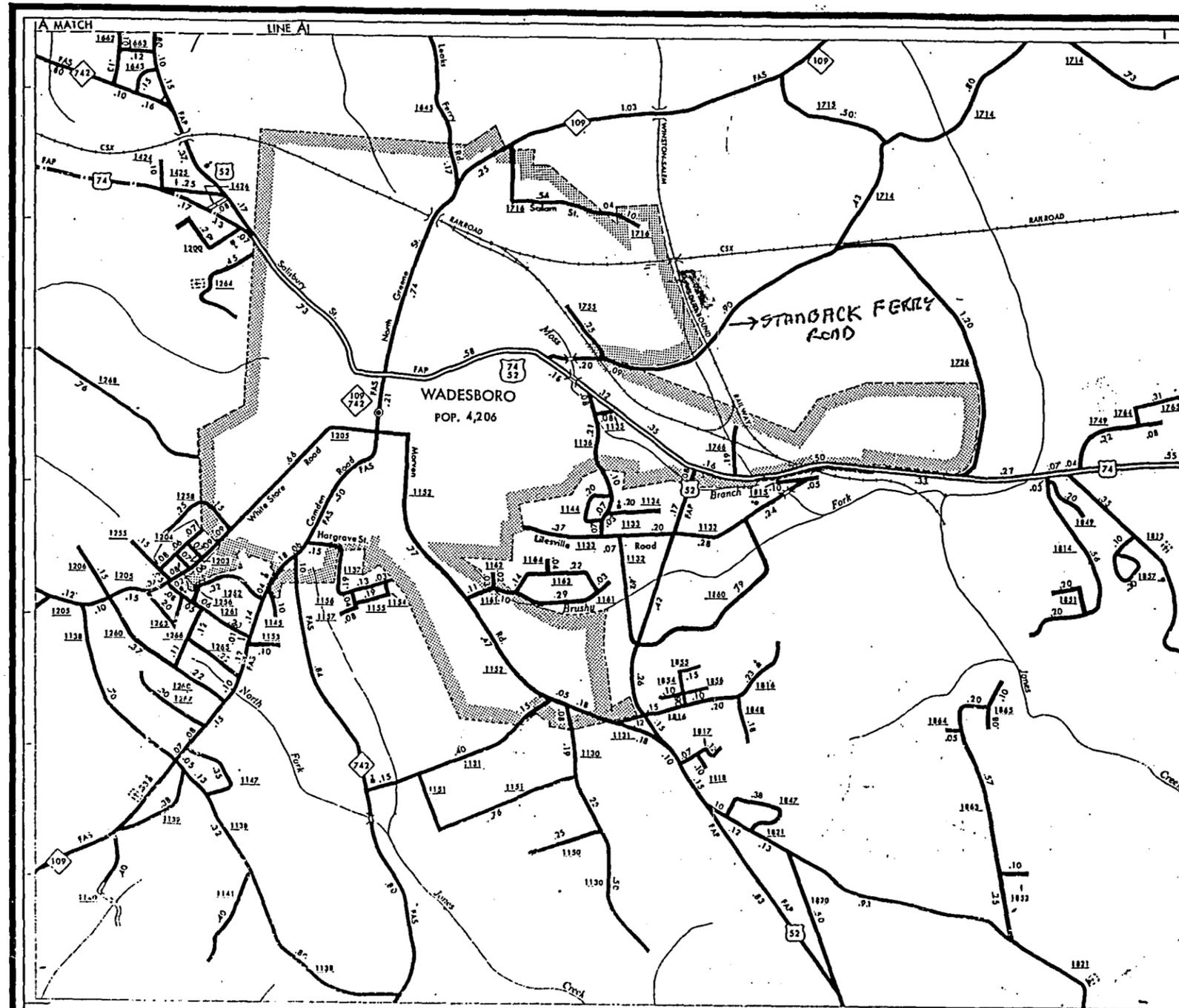
Dan LaMontagne, Head
Site Evaluation and Removal Branch
NC Superfund Section

Attachments

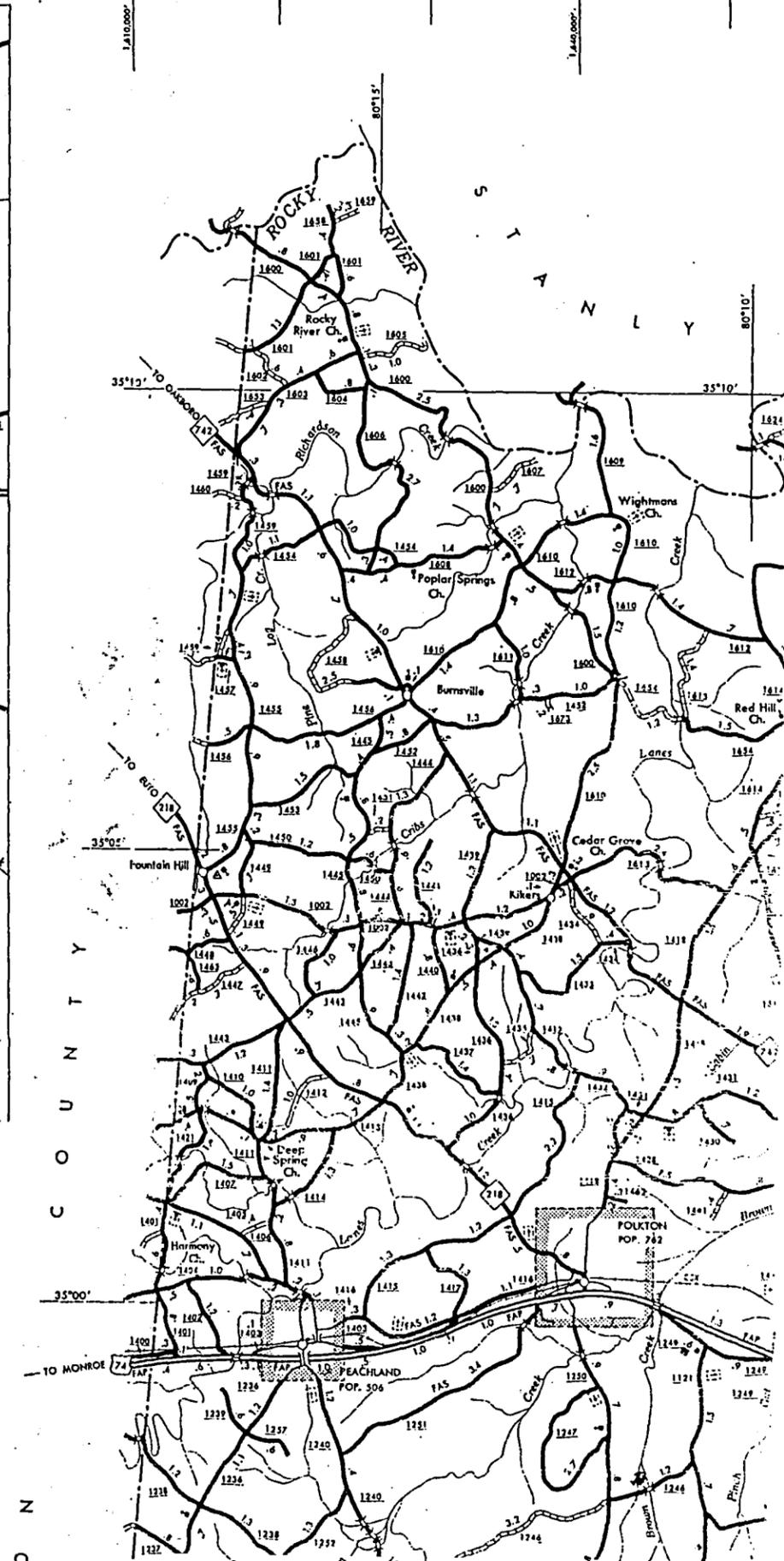
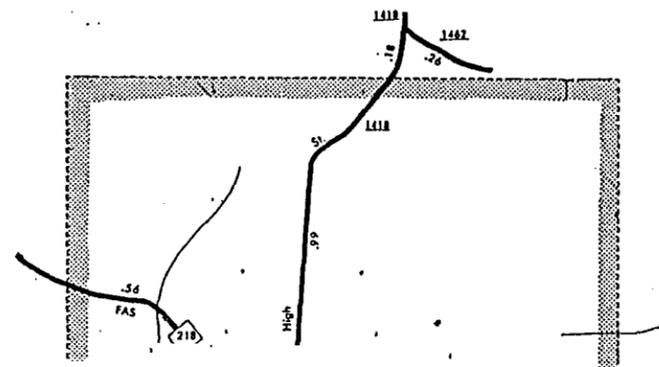
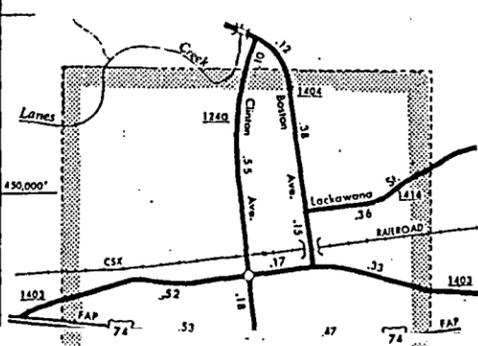
1. Road Map to Site
2. Site Lat. / Long. Worksheet
3. Metals Analysis Results

Mr. Lair
October 22, 1999
Page 3 of 3

cc:	w/ attachments	letter only
	File	Jack Butler, DWM
	Scott Ryals, DWM	Charlotte Jesneck, DWM
	Don Rigger, US EPA	Phil Vorsatz, US EPA
	Mr. Carl Weston, Property Owner	
	Carol Gibson, Anson County Health Department	
	Jennifer Wendel, US EPA	
	Ken Mallory, US EPA	



WADESBORO AND VICINITY



LATITUDE AND LONGITUDE CALCULATION WORKSHEET #2
 LI USING ENGINEER'S SCALE (1/60)

SITE NAME: VC Chemical - Wadesboro CERCLIS #: NCSTN 0406 924

AKA: _____ SSID: _____

ADDRESS: Stankovic Ferry Rd

CITY: Wadesboro STATE: NC ZIP CODE: _____

SITE REFERENCE POINT: North edge of Five Pond

USGS QUAD MAP NAME: _____ TOWNSHIP: _____ N/S RANGE: _____ E/W

SCALE: 1:24,000 MAP DATE: 1956/1978 SECTION: _____ 1/4 _____ 1/4 _____ 1/4

MAP DATUM: 1927 1983 (CIRCLE ONE) MERIDIAN: _____

COORDINATES FROM LOWER RIGHT (SOUTHEAST) CORNER OF 7.5' MAP (attach photocopy):

LONGITUDE: 80° 00' 06" LATITUDE: 34° 52' 30"

COORDINATES FROM LOWER RIGHT (SOUTHEAST) CORNER OF 2.5' GRID CELL:

LONGITUDE: 80° 02' 30" LATITUDE: 34° 57' 30"

CALCULATIONS: LATITUDE (7.5' QUADRANGLE MAP)

A) NUMBER OF RULER GRADUATIONS FROM LATITUDE GRID LINE TO SITE REF POINT: 156

B) MULTIPLY (A) BY 0.3304 TO CONVERT TO SECONDS:

$$A \times 0.3304 = \underline{51.54}''$$

C) EXPRESS IN MINUTES AND SECONDS (1' = 60"): .52"

D) ADD TO STARTING LATITUDE: 34° 57' 30" + .52" =

SITE LATITUDE: 34° 58' 22"

CALCULATIONS: LONGITUDE (7.5' QUADRANGLE MAP)

A) NUMBER OF RULER GRADUATIONS FROM RIGHT LONGITUDE LINE TO SITE REF POINT: 167

B) MULTIPLY (A) BY 0.3304 TO CONVERT TO SECONDS:

$$A \times 0.3304 = \underline{55.84}''$$

C) EXPRESS IN MINUTES AND SECONDS (1' = 60"): .56"

D) ADD TO STARTING LONGITUDE: 80° 02' 30" + .56" =

SITE LONGITUDE: 80° 03' 26"

INVESTIGATOR: Scott C. Lynch

DATE: 10/20/99

Site Number NCS FWO 406 924 Sample ID Number VC-001-SL 07/26/99 1220 GRAB
VC072699, NC S. RYALS
 Name of Site Virginia Carolina Chemical Collected By INORG-CLP METALS Soil
VCW-27 59
 Site Location Windsboro, NC Date Collected _____

Agency: Hazardous Waste Solid Waste Superfund

Sample Type		Comments
Environmental	Concentrate	
<input type="checkbox"/> Ground Water (1)	<input type="checkbox"/> Solid (5)	
<input type="checkbox"/> Surface Water (2)	<input type="checkbox"/> Liquid (6)	
<input checked="" type="checkbox"/> Soil (3)	<input type="checkbox"/> Sludge (7)	<u>Background</u>
<input type="checkbox"/> Other (4)	<input type="checkbox"/> Other (8)	

TCLP Compounds	
Inorganic Compounds	Results(mg/l)
<input type="checkbox"/> arsenic	
<input type="checkbox"/> barium	
<input type="checkbox"/> cadmium	
<input type="checkbox"/> chromium	
<input type="checkbox"/> lead	
<input type="checkbox"/> mercury	
<input type="checkbox"/> selenium	
<input type="checkbox"/> silver	

Organic Chemistry	Results (mg/l)
<input type="checkbox"/> P&T:GC/MS	
<input type="checkbox"/> Acid:B/N Ext.	
<input type="checkbox"/> 2,4-D	
<input type="checkbox"/> 2,4,5-TP(Silvex)	
<input type="checkbox"/> chlordane	
<input type="checkbox"/> heptachlor	
<input type="checkbox"/> hexachlorobenzene	
<input type="checkbox"/> hexachlorobutadiene	
<input type="checkbox"/> endrin	
<input type="checkbox"/> lindane	
<input type="checkbox"/> methoxychlor	
<input type="checkbox"/> toxaphene	

Inorganic Chemistry	Results(mg/l)/(mg/kg)
<input type="checkbox"/> antimony	
<input checked="" type="checkbox"/> arsenic	<u><4</u>
<input checked="" type="checkbox"/> barium	<u>20</u>
<input checked="" type="checkbox"/> beryllium	<u><6</u>
<input checked="" type="checkbox"/> cadmium	<u><4</u>
<input type="checkbox"/> chloride	
<input checked="" type="checkbox"/> chromium	<u>8</u>
<input type="checkbox"/> cobalt	
<input checked="" type="checkbox"/> copper	<u><10</u>
<input type="checkbox"/> fluoride	
<input type="checkbox"/> iron	
<input checked="" type="checkbox"/> lead	<u>4</u>
<input type="checkbox"/> manganese	
<input checked="" type="checkbox"/> mercury	<u><0.20</u>
<input type="checkbox"/> nickel	
<input checked="" type="checkbox"/> nitrate(as N)	<u><20</u>
<input checked="" type="checkbox"/> selenium	<u><2</u>
<input checked="" type="checkbox"/> silver	<u><4</u>
<input checked="" type="checkbox"/> sulfates	<u><100</u>
<input type="checkbox"/> thallium	
<input checked="" type="checkbox"/> vanadium	<u>10</u>
<input type="checkbox"/> zinc	
<input type="checkbox"/> pH	
<input type="checkbox"/> conductivity	
<input type="checkbox"/> TDS	
<input type="checkbox"/> flash point	

Organic Compounds	Results(mg/l)
<input type="checkbox"/> benzene	
<input type="checkbox"/> carbon tetrachloride	
<input type="checkbox"/> chlordane	
<input type="checkbox"/> chlorobenzene	
<input type="checkbox"/> chloroform	
<input type="checkbox"/> o-cresol	
<input type="checkbox"/> m-cresol	
<input type="checkbox"/> p-cresol	
<input type="checkbox"/> cresol	
<input type="checkbox"/> 1,4-dichlorobenzene	
<input type="checkbox"/> 1,2-dichloroethane	
<input type="checkbox"/> 1,1-dichloroethylene	
<input type="checkbox"/> 2,4-dichloroethylene	
<input type="checkbox"/> heptachlor	
<input type="checkbox"/> hexachlorobenzene	
<input type="checkbox"/> hexachlorobutadiene	
<input type="checkbox"/> hexachloroethane	
<input type="checkbox"/> methyl ethyl ketone	
<input type="checkbox"/> nitrobenzene	
<input type="checkbox"/> pentachlorophenol	
<input type="checkbox"/> pyridine	
<input type="checkbox"/> tetrachloroethylene	
<input type="checkbox"/> trichloroethylene	
<input type="checkbox"/> 2,4,5-trichlorophenol	
<input type="checkbox"/> 2,4,6-trichlorophenol	
<input type="checkbox"/> vinyl chloride	
<input type="checkbox"/> endrin	
<input type="checkbox"/> lindane	
<input type="checkbox"/> methoxychlor	
<input type="checkbox"/> toxaphene	
<input type="checkbox"/> 2,4-D	
<input type="checkbox"/> 2,4,5-TP (Silvex)	

FOR LAB USE ONLY

Date Received _____

Date Extracted _____

Date Analyzed _____

Reported By DM

Date Reported 8/25/99

Lab Number 010983 JUL 2799

Site Number NC SFN 0406924 Sample ID Number/N. VC-002-SL 07/26/99 1305 GRAB
VC072699, NC S. RYALS
 Name of Site Virginia Carolina Chemical Collected By INORG-CLP METALS Soil
VCW-31 67
 Site Location Wadesboro, NC Date Collected _____

Agency: Hazardous Waste Solid Waste Superfund

Sample Type		Comments
Environmental	Concentrate	
<input type="checkbox"/> Ground Water (1)	<input type="checkbox"/> Solid (5)	_____
<input type="checkbox"/> Surface Water (2)	<input type="checkbox"/> Liquid (6)	_____
<input type="checkbox"/> Soil (3)	<input type="checkbox"/> Sludge (7)	_____
<input type="checkbox"/> Other (4)	<input type="checkbox"/> Other (8)	_____

TCLP Compounds	
Inorganic Compounds	Results(mg/l)
<input checked="" type="checkbox"/> arsenic	<u><0.02</u>
<input type="checkbox"/> barium	_____
<input type="checkbox"/> cadmium	_____
<input type="checkbox"/> chromium	_____
<input checked="" type="checkbox"/> lead	<u>36.6</u>
<input type="checkbox"/> mercury	_____
<input type="checkbox"/> selenium	_____
<input type="checkbox"/> silver	_____

Organic Chemistry	
Parameter	Results (mg/l)
<input type="checkbox"/> P&T:GC/MS	_____
<input type="checkbox"/> Acid:B/N Ext.	_____
<input type="checkbox"/> 2,4-D	_____
<input type="checkbox"/> 2,4,5-TP(Silvex)	_____
<input type="checkbox"/> chlordane	_____
<input type="checkbox"/> heptachlor	_____
<input type="checkbox"/> hexachlorobenzene	_____
<input type="checkbox"/> hexachlorobutadiene	_____
<input type="checkbox"/> endrin	_____
<input type="checkbox"/> lindane	_____
<input type="checkbox"/> methoxychlor	_____
<input type="checkbox"/> toxaphene	_____

Inorganic Chemistry	
Parameter	Results(mg/l)(mg/kg)
<input type="checkbox"/> antimony	_____
<input checked="" type="checkbox"/> arsenic	<u>32</u>
<input checked="" type="checkbox"/> barium	<u>349</u>
<input checked="" type="checkbox"/> beryllium	<u><6</u>
<input checked="" type="checkbox"/> cadmium	<u><4</u>
<input type="checkbox"/> chloride	_____
<input checked="" type="checkbox"/> chromium	<u><4</u>
<input type="checkbox"/> cobalt	_____
<input checked="" type="checkbox"/> copper	<u>95</u>
<input type="checkbox"/> fluoride	_____
<input type="checkbox"/> iron	_____
<input checked="" type="checkbox"/> lead	<u>3002</u>
<input type="checkbox"/> manganese	_____
<input checked="" type="checkbox"/> mercury	<u>0.30</u>
<input type="checkbox"/> nickel	_____
<input checked="" type="checkbox"/> nitrate(as N)	<u><10</u>
<input checked="" type="checkbox"/> selenium	<u>6</u>
<input checked="" type="checkbox"/> silver	<u>10</u>
<input checked="" type="checkbox"/> sulfates	<u>559</u>
<input type="checkbox"/> thallium	_____
<input checked="" type="checkbox"/> vanadium	<u><6</u>
<input type="checkbox"/> zinc	_____
<input type="checkbox"/> pH	_____
<input type="checkbox"/> conductivity	_____
<input type="checkbox"/> TDS	_____
<input type="checkbox"/> flash point	_____

Organic Compounds	Results(mg/l)
<input type="checkbox"/> benzene	_____
<input type="checkbox"/> carbon tetrachloride	_____
<input type="checkbox"/> chlordane	_____
<input type="checkbox"/> chlorobenzene	_____
<input type="checkbox"/> chloroform	_____
<input type="checkbox"/> o-cresol	_____
<input type="checkbox"/> m-cresol	_____
<input type="checkbox"/> p-cresol	_____
<input type="checkbox"/> cresol	_____
<input type="checkbox"/> 1,4-dichlorobenzene	_____
<input type="checkbox"/> 1,2-dichloroethane	_____
<input type="checkbox"/> 1,1-dichloroethylene	_____
<input type="checkbox"/> 2,4-dichloroethylene	_____
<input type="checkbox"/> heptachlor	_____
<input type="checkbox"/> hexachlorobenzene	_____
<input type="checkbox"/> hexachlorobutadiene	_____
<input type="checkbox"/> hexachloroethane	_____
<input type="checkbox"/> methyl ethyl ketone	_____
<input type="checkbox"/> nitrobenzene	_____
<input type="checkbox"/> pentachlorophenol	_____
<input type="checkbox"/> pyridine	_____
<input type="checkbox"/> tetrachloroethylene	_____
<input type="checkbox"/> trichloroethylene	_____
<input type="checkbox"/> 2,4,5-trichlorophenol	_____
<input type="checkbox"/> 2,4,6-trichlorophenol	_____
<input type="checkbox"/> vinyl chloride	_____
<input type="checkbox"/> endrin	_____
<input type="checkbox"/> lindane	_____
<input type="checkbox"/> methoxychlor	_____
<input type="checkbox"/> toxaphene	_____
<input type="checkbox"/> 2,4-D	_____
<input type="checkbox"/> 2,4,5-TP (Silvex)	_____

FOR LAB USE ONLY

Date Received _____
 Date Extracted _____
 Date Analyzed _____
 Reported By DM
 Date Reported 8/25/99
 Lab Number 110984 JUL 2759

SAMPLE ANALYSIS REQUEST

Site Number NC SFN 0406924 Sample ID Number VC-006-SL 07/26/99 1318 GRAB
VC072699, NC S. RYALS
 Name of Site Virginia Carolina Chemical Collected By INORG-CLP METALS Soil 108
 Site Location Wadesboro, NC Date Collected VCW-47

Agency: Hazardous Waste Solid Waste Superfund

Sample Type		Comments
Environmental	Concentrate	
<input type="checkbox"/> Ground Water (1)	<input type="checkbox"/> Solid (5)	
<input type="checkbox"/> Surface Water (2)	<input type="checkbox"/> Liquid (6)	
<input type="checkbox"/> Soil (3)	<input type="checkbox"/> Sludge (7)	
<input type="checkbox"/> Other (4)	<input type="checkbox"/> Other (8)	

TCLP Compounds	
Inorganic Compounds	Results(mg/l)
<input checked="" type="checkbox"/> arsenic	<u><0.02</u>
<input type="checkbox"/> barium	
<input type="checkbox"/> cadmium	
<input type="checkbox"/> chromium	
<input checked="" type="checkbox"/> lead	<u>5.00</u>
<input type="checkbox"/> mercury	
<input type="checkbox"/> selenium	
<input type="checkbox"/> silver	

Organic Chemistry	Results (mg/l)
<input type="checkbox"/> P&T:GC/MS.	
<input type="checkbox"/> Acid:B/N Ext.	
<input type="checkbox"/> 2,4-D	
<input type="checkbox"/> 2,4,5-TP(Silvex)	
<input type="checkbox"/> chlordane	
<input type="checkbox"/> heptachlor	
<input type="checkbox"/> hexachlorobenzene	
<input type="checkbox"/> hexachlorobutadiene	
<input type="checkbox"/> endrin	
<input type="checkbox"/> lindane	
<input type="checkbox"/> methoxychlor	
<input type="checkbox"/> toxaphene	

Inorganic Chemistry	Results(mg/l)(mg/kg)
<input type="checkbox"/> antimony	
<input checked="" type="checkbox"/> arsenic	<u>12</u>
<input checked="" type="checkbox"/> barium	<u>134</u>
<input checked="" type="checkbox"/> beryllium	<u><6</u>
<input checked="" type="checkbox"/> cadmium	<u><4</u>
<input type="checkbox"/> chloride	
<input checked="" type="checkbox"/> chromium	<u>6</u>
<input type="checkbox"/> cobalt	
<input checked="" type="checkbox"/> copper	<u>51</u>
<input type="checkbox"/> fluoride	
<input type="checkbox"/> iron	
<input checked="" type="checkbox"/> lead	<u>591</u>
<input type="checkbox"/> manganese	
<input checked="" type="checkbox"/> mercury	<u><0.20</u>
<input type="checkbox"/> nickel	
<input checked="" type="checkbox"/> nitrate (60N)	<u><10</u>
<input checked="" type="checkbox"/> selenium	<u><2</u>
<input checked="" type="checkbox"/> silver	<u><4</u>
<input checked="" type="checkbox"/> sulfates	<u>90</u>
<input type="checkbox"/> thallium	
<input checked="" type="checkbox"/> vanadium	<u>10</u>
<input type="checkbox"/> zinc	
<input type="checkbox"/> pH	
<input type="checkbox"/> conductivity	
<input type="checkbox"/> TDS	
<input type="checkbox"/> flash point	

Organic Compounds	Results(mg/l)
<input type="checkbox"/> benzene	
<input type="checkbox"/> carbon tetrachloride	<u>1</u>
<input type="checkbox"/> chlordane	
<input type="checkbox"/> chlorobenzene	
<input type="checkbox"/> chloroform	
<input type="checkbox"/> o-cresol	
<input type="checkbox"/> m-cresol	
<input type="checkbox"/> p-cresol	
<input type="checkbox"/> cresol	
<input type="checkbox"/> 1,4-dichlorobenzene	
<input type="checkbox"/> 1,2-dichloroethane	
<input type="checkbox"/> 1,1-dichloroethylene	
<input type="checkbox"/> 2,4-dichloroethylene	
<input type="checkbox"/> heptachlor	
<input type="checkbox"/> hexachlorobenzene	
<input type="checkbox"/> hexachlorobutadiene	
<input type="checkbox"/> hexachloroethane	
<input type="checkbox"/> methyl ethyl ketone	
<input type="checkbox"/> nitrobenzene	
<input type="checkbox"/> pentachlorophenol	
<input type="checkbox"/> pyridine	
<input type="checkbox"/> tetrachloroethylene	
<input type="checkbox"/> trichloroethylene	
<input type="checkbox"/> 2,4,5-trichlorophenol	
<input type="checkbox"/> 2,4,6-trichlorophenol	
<input type="checkbox"/> vinyl chloride	
<input type="checkbox"/> endrin	
<input type="checkbox"/> lindane	
<input type="checkbox"/> methoxychlor	
<input type="checkbox"/> toxaphene	
<input type="checkbox"/> 2,4-D	
<input type="checkbox"/> 2,4,5-TP (Silvex)	

FOR LAB USE ONLY

Date Received _____
 Date Extracted _____
 Date Analyzed _____
 Reported By DM
 Date Reported 8/25/99
010989 JUL 27 99
 Lab Number _____

SAMPLE ANALYSIS REQUEST

Site Number NC SFN 0406924 Sample ID Number/i VC-008-SL 07/26/99 1240 GRAB
VC072699, NC S. RYALS
 Name of Site Virginia Carolina Chemical Collected By _____
 Site Location Wadesboro, NC Date Collected _____
 INORG-CLP METALS Soil
 VCW-51 116

Agency: Hazardous Waste Solid Waste Superfund

Sample Type		Comments
Environmental	Concentrate	
<input type="checkbox"/> Ground Water (1)	<input type="checkbox"/> Solid (5)	_____
<input type="checkbox"/> Surface Water (2)	<input type="checkbox"/> Liquid (6)	_____
<input type="checkbox"/> Soil (3)	<input type="checkbox"/> Sludge (7)	_____
<input type="checkbox"/> Other (4)	<input type="checkbox"/> Other (8)	_____

TCLP Compounds	
Inorganic Compounds	Results(mg/l)
<input checked="" type="checkbox"/> arsenic	<u><0.02</u>
<input type="checkbox"/> barium	_____
<input type="checkbox"/> cadmium	_____
<input type="checkbox"/> chromium	_____
<input checked="" type="checkbox"/> lead	<u>0.02</u>
<input type="checkbox"/> mercury	_____
<input type="checkbox"/> selenium	_____
<input type="checkbox"/> silver	_____

Organic Chemistry	
Parameter	Results (mg/l)
<input type="checkbox"/> P&T:GC/MS.	_____
<input type="checkbox"/> Acid:B/N Ext.	_____
<input type="checkbox"/> 2,4-D	_____
<input type="checkbox"/> 2,4,5-TP(Silvex)	_____
<input type="checkbox"/> chlordane	_____
<input type="checkbox"/> heptachlor	_____
<input type="checkbox"/> hexachlorobenzene	_____
<input type="checkbox"/> hexachlorobutadiene	_____
<input type="checkbox"/> endrin	_____
<input type="checkbox"/> lindane	_____
<input type="checkbox"/> methoxychlor	_____
<input type="checkbox"/> toxaphene	_____

Inorganic Chemistry	
Parameter	Results(mg/l)(mg/kg)
<input type="checkbox"/> antimony	_____
<input checked="" type="checkbox"/> arsenic	<u>92</u>
<input checked="" type="checkbox"/> barium	<u>371</u>
<input checked="" type="checkbox"/> beryllium	<u><6</u>
<input checked="" type="checkbox"/> cadmium	<u>4</u>
<input type="checkbox"/> chloride	_____
<input checked="" type="checkbox"/> chromium	<u><4</u>
<input type="checkbox"/> cobalt	_____
<input checked="" type="checkbox"/> copper	<u>1042</u>
<input type="checkbox"/> fluoride	_____
<input type="checkbox"/> iron	_____
<input checked="" type="checkbox"/> lead	<u>329</u>
<input type="checkbox"/> manganese	_____
<input checked="" type="checkbox"/> mercury	<u><0.20</u>
<input type="checkbox"/> nickel	_____
<input checked="" type="checkbox"/> nitrate (as N)	<u><10</u>
<input checked="" type="checkbox"/> selenium	<u><2</u>
<input checked="" type="checkbox"/> silver	<u>4</u>
<input checked="" type="checkbox"/> sulfates	<u>7480</u>
<input type="checkbox"/> thallium	_____
<input checked="" type="checkbox"/> vanadium	<u>6</u>
<input type="checkbox"/> zinc	_____
<input type="checkbox"/> pH	_____
<input type="checkbox"/> conductivity	_____
<input type="checkbox"/> TDS	_____
<input type="checkbox"/> flash point	_____

Organic Compounds	Results(mg/l)
<input type="checkbox"/> benzene	_____
<input type="checkbox"/> carbon tetrachloride	_____
<input type="checkbox"/> chlordane	_____
<input type="checkbox"/> chlorobenzene	_____
<input type="checkbox"/> chloroform	_____
<input type="checkbox"/> o-cresol	_____
<input type="checkbox"/> m-cresol	_____
<input type="checkbox"/> p-cresol	_____
<input type="checkbox"/> cresol	_____
<input type="checkbox"/> 1,4-dichlorobenzene	_____
<input type="checkbox"/> 1,2-dichloroethane	_____
<input type="checkbox"/> 1,1-dichloroethylene	_____
<input type="checkbox"/> 2,4-dichloroethylene	_____
<input type="checkbox"/> heptachlor	_____
<input type="checkbox"/> hexachlorobenzene	_____
<input type="checkbox"/> hexachlorobutadiene	_____
<input type="checkbox"/> hexachloroethane	_____
<input type="checkbox"/> methyl ethyl ketone	_____
<input type="checkbox"/> nitrobenzene	_____
<input type="checkbox"/> pentachlorophenol	_____
<input type="checkbox"/> pyridine	_____
<input type="checkbox"/> tetrachloroethylene	_____
<input type="checkbox"/> trichloroethylene	_____
<input type="checkbox"/> 2,4,5-trichlorophenol	_____
<input type="checkbox"/> 2,4,6-trichlorophenol	_____
<input type="checkbox"/> vinyl chloride	_____
<input type="checkbox"/> endrin	_____
<input type="checkbox"/> lindane	_____
<input type="checkbox"/> methoxychlor	_____
<input type="checkbox"/> toxaphene	_____
<input type="checkbox"/> 2,4-D	_____
<input type="checkbox"/> 2,4,5-TP (Silvex)	_____

FOR LAB USE ONLY

Date Received _____
 Date Extracted _____
 Date Analyzed _____
 Reported By [Signature]
 Date Reported 8/25/99
 Lab Number 010990 JUL 2799

Publication 9345.1-21
EPA/540/R-96/028
PB96-963509
June 1996

Superfund Chemical Data Matrix

Office of Emergency and Remedial Response
U.S. Environmental Protection Agency
Washington, DC 20460

HAZARD RANKING SYSTEM
 Hazardous Substance Benchmarks
 376 Substances

SOIL PATHWAY

Substance Name	CAS Number	Reference Dose Screen Conc (mg/kg)	Cancer Risk Screen Conc (mg/kg)
Ammonium picrate	000131-74-8	...	...
Ammonium sulfamate	007773-06-0	1.6E+04*	...
Aniline	000062-53-3	...	1.1E+02*
Anthracene	000120-12-7	2.3E+04*	...
Antimony	007440-36-0	3.1E+01*	...
Arsenic	007440-38-2	2.3E+01*	4.3E-01*
Asbestos	001332-21-4	...	...
Atrazine	001912-24-9	2.7E+03*	2.9E+00*
Azinphos- ethyl	002642-71-9	...	...
Azinphos- methyl	000086-50-0	...	...
Aziridine	000151-56-4	...	...
Barium	007440-39-3	5.5E+03*	...
Barium cyanide	000542-62-1	... *	...
Benz(a)anthracene	000056-55-3	...	8.8E-01*
Benzene	000071-43-2	...	2.2E+01*
Benzene carbonyl chloride	000098-88-4	...	...
Benzidine	000092-87-5	2.3E+02*	2.8E-03*
Benzo(a)pyrene	000050-32-8	...	8.8E-02*

* Indicates difference between previous version of chemical data (JUN94) and current version of chemical data (JUN96);
 ** Indicates new hazardous substance in current version of chemical data (JUN96).

HAZARD RATING SYSTEM
 Hazardous Substance Benchmarks
 376 Substances

SOIL PATHWAY

Substance Name	CAS Number	Reference Dose Screen Conc (mg/kg)	Cancer Risk Screen Conc (mg/kg)
Chlorine cyanide	000506-77-4	3.9E+03*	...
Chloro-3-methylphenol, 4-	000059-50-7	1.6E+05*	...
Chloroaniline, p-	000106-47-8	3.1E+02*	...
Chlorobenzene	000108-90-7	1.6E+03*	...
Chlorobenzilate**	000510-15-6	1.6E+03	2.4E+00
Chloroform	000067-66-3	7.8E+02*	1.0E+02*
Chloromethane	000074-87-3	...	4.9E+01*
Chloromethyl methyl ether	000107-30-2	...	...
Chloromethyloxirane, 2-	000106-89-8	1.6E+02*	6.5E+01*
Chloronaphthalene, 2-	000091-58-7	6.3E+03*	...
Chlorophenol, 2-	000095-57-8	3.9E+02*	...
Chlorophenyl-phenyl ether, 4-**	007005-72-3	...	...
Chloroprene**	000126-99-8	...	...
Chlorpyrifos	002921-88-2	2.3E+02*	...
Chromium	007440-47-3	3.9E+02*	...
Chromium(III)	016065-83-1	7.8E+04*	...
Chromium(VI)	018540-29-9	3.9E+02*	...
Chrysene	000218-01-9	...	8.8E+01*

* Indicates difference between previous version of chemical data (JUN94) and current version of chemical data (JUN96).

** Indicates new hazardous substance in current version of chemical data (JUN96).

HAZARD RANKING SYSTEM
Hazardous Substance Benchmarks
376 Substances

SOIL PATHWAY

Substance Name	CAS Number	Reference Dose Screen Conc (mg/kg)	Cancer Risk Screen Conc (mg/kg)
Isophorone	000078-59-1	1.6E+04*	6.7E+02*
KENZENE**	00000000000	...	...
Kepone	000143-50-0	...	...
Lead	007439-92-1	...	...
Lindane	000058-89-9	2.3E+01*	4.9E-01*
Magnesium	007439-95-4	...	...
Malathion	000121-75-5	1.6E+03*	...
Maleic anhydride	000108-31-6	7.8E+03*	...
Maleic hydrazide	000123-33-1	3.9E+04*	...
Manganese	007439-96-5	1.1E+04*	...
Mercury	007439-97-6	2.3E+01*	...
Methacrylonitrile	000126-98-7	7.8E+00*	...
Methanol	000067-56-1	3.9E+04*	...
Methomyl	016752-77-5	2.0E+03*	...
Methoxychlor	000072-43-5	3.9E+02*	...
Methyl chlorocarbonate	000079-22-1	...	...
Methyl ethyl ketone	000078-93-3	4.7E+04*	...
Methyl isobutyl ketone	000108-10-1	6.3E+03*	...
Methyl methacrylate	000080-62-6	6.3E+03*	...

* Indicates difference between previous version of chemical data (JUN94) and current version of chemical data (JUN96).

** Indicates new hazardous substance in current version of chemical data (JUN96).

HAZARD RANKING SYSTEM
 Hazardous Substance Benchmarks
 376 Substances

Substance Name	CAS. Number	SOIL PATHWAY	
		Reference Dose Screen Conc (mg/kg)	Cancer Risk Screen Conc (mg/kg)
Phosphoric acid	007664-38-2	...	...
Phosphorous (elemental)	007723-14-0	1.6E+00*	...
Phthalic anhydride	000085-44-9	1.6E+05*	...
Plutonium	007440-07-5	...	...
Polychlorinated triphenyl	012642-23-8	...	...
Potassium**	007440-09-7	...	...
Potassium silver cyanide	000506-61-6	1.6E+04*	...
Pronamide	023950-58-5	5.9E+03*	...
Pyrene	000129-00-0	2.3E+03*	...
Pyridine	000110-86-1	7.8E+01*	...
Quinoline	000091-22-5	...	5.3E-02*
Radium	007440-14-4	...	...
Radon	010043-92-2	...	...
Resorcinol	000108-46-3	...	...
Ronnel	000299-84-3	3.9E+03*	...
Safrole**	000094-59-7	...	...
Selenium	007782-49-2	3.9E+02*	...
Selenourea	000630-10-4	3.9E+02*	...

* Indicates difference between previous version of chemical data (JUN94) and current version of chemical data (JUN96).

** Indicates new hazardous substance in current version of chemical data (JUN96).

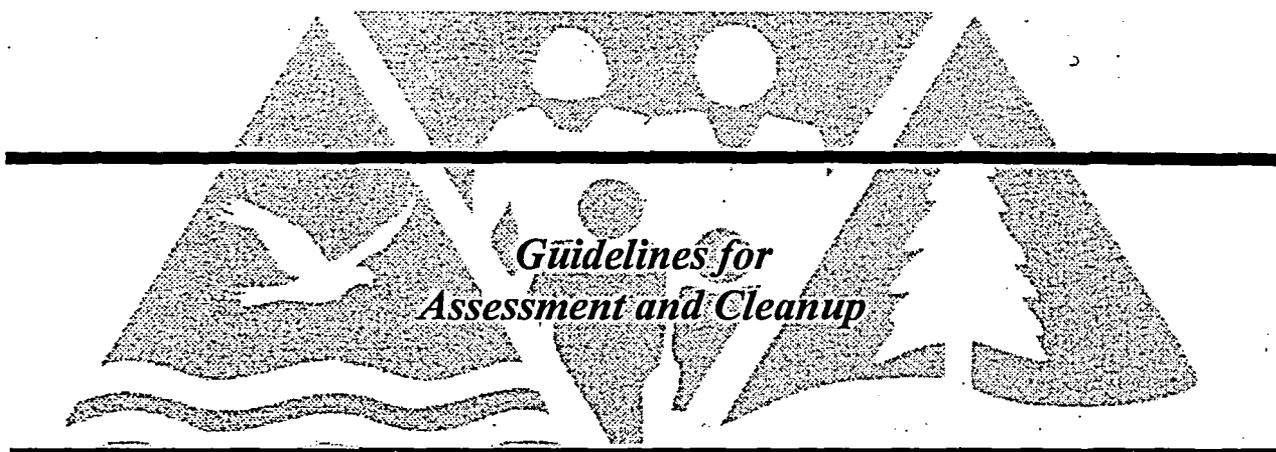
HAZARD RANKING SYSTEM
 Hazardous Substance Benchmarks
 376 Substances

SOIL PATHWAY

Substance Name	CAS Number	Reference Dose Screen Conc (mg/kg)	Cancer Risk Screen Conc (mg/kg)
Trichlorophenol, 2,4,6-	000088-06-2	...	5.8E+01*
Trichlorophenol, 3,4,5-	000609-19-8	...	...
Trichlorophenoxyacetic acid, 2,4,5-	000093-76-5	7.8E+02*	...
Trichloropropane, 1,2,3-	000096-18-4	4.7E+02*	9.1E-02*
Triethanolamine	000102-71-6	...	...
Trifluralin	001582-09-8	5.9E+02*	8.3E+01*
Trinitrobenzene, 1,3,5-	000099-35-4	3.9E+00*	...
Trinitrotoluene	000118-96-7	3.9E+01*	2.1E+01*
Tris (2,3-dibromopropyl) phosphate	000126-72-7	...	...
Vanadium	007440-62-2	5.5E+02*	...
Vanadium pentoxide	001314-62-1	7.0E+02*	...
Vinyl acetate	000108-05-4	7.8E+04*	...
Vinyl chloride	000075-01-4	...	3.4E-01*
Warfarin	000081-81-2	2.3E+01*	...
Xylene, m-	000108-38-3	1.6E+05*	...
Xylene, o-	000095-47-6	1.6E+05*	...
Xylene, p-	000106-42-3	...	...
Zinc	007440-66-6	2.3E+04*	...

* Indicates difference between previous version of chemical data (JUN94) and current version of chemical data (JUN96).
 ** Indicates a hazardous substance in current version of chemical data (JUN96).

Inactive Hazardous Sites Program



August 1998

NCDENR

NORTH CAROLINA DEPARTMENT OF
ENVIRONMENT AND NATURAL RESOURCES

North Carolina Department of Environment and Natural Resources
Division of Waste Management
Superfund Section
Inactive Hazardous Sites Branch

401 Oberlin Road - Suite 150
Raleigh, North Carolina 27605
Telephone: (919) 733-2801

Table D-1: Soil Remediation Goals (RG's)¹

*Hazardous substances identified with an asterisk exhibit both carcinogenic and non-carcinogenic effects. The carcinogenic remediation goal is listed because it is more stringent at the $1.0E^{-6}$ risk concentration than the remediation goal for non-carcinogenic effects. See Appendix E for procedures to calculate remediation goals for chemicals not listed on the table. Cleanup below method detection limits, using analytical methods prescribed in the guidelines, is not required.

Chemical	CASRN	RG (ppm)	
Acetone	67641	1560	N
Acetone cyanohydrin	75865	1100	N
Acetonitrile	75078	94	N
Acetophenone	98862	1560	N
Acrolein	107028	320	N
Acrylamide *	79061	0.14	C
Acrylic acid	79107	7800	N
Acrylonitrile *	107131	1.2	C
Aldicarb	116063	15.6	N
Aldrin *	309002	0.038	C
Allyl alcohol	107186	78	N
Allyl chloride	107051	780	N
4-Aminopyridine	504245	0.32	N
Ammonium sulfamate	7773060	3200	N
Aniline	62533	110	C
Antimony and compounds (not listed below)	7440360	6.2	N
Antimony pentoxide	1314609	7.8	N
Antimony potassium tartrate	304610	14	N
Antimony tetroxide	1332316	6.2	N
Antimony trioxide	1309644	6.2	N
Arsenic	7440382	4.6	N
Benzene	71432	22	C
Benzenethiol	108985	0.156	N
Benzidine *	92875	0.0028	C
Benzoic acid	65850	62000	N
Benzotrichloride	98077	0.049	C
Benzyl chloride	100447	3.8	C
Beryllium and compounds *	7440417	0.15	C
alpha BHC	319846	0.1	C
beta BHC	319857	0.35	C
gamma BHC (Lindane)*	58899	0.49	C

- 1 - Adapted from USEPA Region III Risk Based Concentration Table, except as noted.
- 2 - The RG is 1 ppm from 0-10 inches and 10 ppm below 10 inches.
- C - The RG is based on the carcinogenic endpoint and corresponds to an excess lifetime cancer risk of 1 in 1,000,000.
- L - The RG is based on USEPA guidance on lead cleanup levels.
- N - The RG is based on the non-carcinogenic endpoint and corresponds to a hazard quotient of 0.2.
- NA - Not Available.
- P - The RG is based on USEPA PCB spill policy.

Table D-1: Soil Remediation Goals (RG's)¹ - (Cont.)

**Hazardous substances identified with an asterisk exhibit both carcinogenic and non-carcinogenic effects. The carcinogenic remediation goal is listed because it is more stringent at the 1.0E⁻⁶ risk concentration than the remediation goal for non-carcinogenic effects. See Appendix E for procedures to calculate remediation goals for chemicals not listed on the table. Cleanup below method detection limits, using analytical methods prescribed in the guidelines, is not required.*

<i>Chemical</i>	<i>CASRN</i>	<i>RG (ppm)</i>	
Chloroform *	67663	100	C
Chloromethane	74873	49	C
beta-Chloronaphthalene	91587	1260	N
o-Chloronitrobenzene	88733	26	C
p-Chloronitrobenzene	100005	35	C
2-Chlorophenol	95578	78	N
o-Chlorotoluene	95498	320	N
Chlorpyrifos	2921882	46	N
Chromium III and compounds	16065831	15600	N
Chromium VI and compounds	18540299	78	N
Copper and compounds	7440508	620	N
Crotonaldehyde *	123739	0.34	C
Cumene	98828	1560	N
Cyanide	57125	320	N
Cyclohexanone	108941	78000	N
2-Cyclohexyl-4,6-dinitrophenol (4,6-Dinitro-o-cyclohexyl phenol)	131895	32	N
Dalapon	75990	460	N
DDD	72548	2.7	C
DDE	72559	1.9	C
DDT*	50293	1.9	C
Diallate	2303164	10	C
Diazinon	333415	14	N
Dibenzofuran	132649	62	N
1,2-Dibromo-3-chloropropane	96128	0.46	C
1,2-Dibromoethane	106934	0.0075	C
Di-n-butyl phthalate	84742	1560	N
Dicamba	1918009	460	N
1,2-Dichlorobenzene	95501	1400	N
1,3-Dichlorobenzene	541731	1400	N
1,4-Dichlorobenzene	106467	27	C
3,3'-Dichlorobenzidine	91941	1.4	C

- 1 - Adapted from USEPA Region III Risk Based Concentration Table, except as noted.
- 2 - The RG is 1 ppm from 0-10 inches and 10 ppm below 10 inches.
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Table D-1: Soil Remediation Goals (RG's)¹ - (Cont.)

**Hazardous substances identified with an asterisk exhibit both carcinogenic and non-carcinogenic effects. The carcinogenic remediation goal is listed because it is more stringent at the 1.0E⁻⁶ risk concentration than the remediation goal for non-carcinogenic effects. See Appendix E for procedures to calculate remediation goals for chemicals not listed on the table. Cleanup below method detection limits, using analytical methods prescribed in the guidelines, is not required.*

Chemical	CASRN	RG (ppm)	
Ethyl ether	60297	3200	N
Ethyl methacrylate	97632	1400	N
Formaldehyde	50000	3200	N
Formic acid	64186	32000	N
Furfural	98011	46	N
Glycidaldehyde	765344	6.2	N
Heptachlor *	76448	0.14	C
Heptachlor epoxide *	1024573	0.07	C
Hexachlorobenzene*	118741	0.4	C
Hexachlorobutadiene *	87683	8.2	C
Hexachlorocyclopentadiene	77474	110	N
Hexachloroethane *	67721	46	C
Hexachlorophene	70304	4.6	N
Hydrazine	302012	0.21	C
Hydrogen sulfide	7783064	46	N
Isophorone *	78591	670	C
Kepone	143500	0.035	C
Lead	7439921	400	L
Malathion	121755	320	N
Maleic anhydride	108316	1560	N
Maleic hydrazide	123331	7800	N
Malononitrile	109773	0.32	N
Mercury (inorganic)	7439976	4.6	N
Methacrylonitrile	126987	1.56	N
Methanol	67561	7800	N
Methomyl	16752775	400	N
Methoxychlor	72435	78	N
2-Methyl benzenamine (2-methylaniline)	95534	2.7	C
2-Methyl benzenamine hydrochloride (2-methylaniline hydrochloride)	636215	3.5	C
Methyl chlorocarbonate	79221	15600	N
4,4'-Methylene bis(2 chloroaniline)*	101144	4.9	C

- 1 - Adapted from USEPA Region III Risk Based Concentration Table, except as noted.
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Chemical	CASRN	RG (ppm)	
Propazine	139402	320	N
Propylene oxide	75569	2.7	C
Pyridine	110861	15.6	N
Quinoline	91225	0.053	C
Selenious acid	7783008	78	N
Selenium	7782492	78	N
Selenourea	630104	78	N
Silver and compounds	7440224	78	N
Sodium azide	26628228	62	N
Sodium fluoroacetate	62748	0.32	N
Strychnine	57249	4.6	N
Styrene	100425	3200	N
1,2,4,5-Tetrachlorobenzene	95943	4.6	N
1,1,2,2-Tetrachloroethane	79345	3.2	C
1,1,1,2-Tetrachloroethane *	630206	25	C
Tetrachloroethylene (PCE)*	127184	12	C
2,3,4,6-Tetrachlorophenol	58902	460	N
p,a,a,a-Tetrachlorotoluene	5216251	0.032	C
Tetraethyldithiopyrophosphate	3689245	7.8	N
Tetraethyl lead	78002	0.00156	N
Thallic oxide	1314325	1.1	N
Thallium	NA	1.26	N
Thallium acetate	563688	1.4	N
Thallium carbonate	6533739	1.26	N
Thallium chloride	7791120	1.26	N
Thallium nitrate	10102451	1.4	N
Thallium selenite	12039520	1.4	N
Thallium sulfate	7446186	1.26	N
Thiofanox	39196184	4.6	N
Thiram	137268	78	N
Toluene	108883	3200	N

- 1 - Adapted from USEPA Region III Risk Based Concentration Table, except as noted.
- 2 - The RG is 1 ppm from 0-10 inches and 10 ppm below 10 inches.
- C - The RG is based on the carcinogenic endpoint and corresponds to an excess lifetime cancer risk of 1 in 1,000,000.
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Table D-1: Soil Remediation Goals (RG's)¹ - (Cont.)

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Chemical	CASRN	RG (ppm)	
Toluene-2,4-diamine	95807	0.2	C
Toluene-2,6-diamine	823405	3200	N
p-Toluidine	106490	3.4	C
Toxaphene	8001352	0.58	C
1,1,2-Trichloro-1,2,2-trifluoroethane	76131	200000	N
1,2,4-Trichlorobenzene	120821	156	N
1,1,1-Trichloroethane	71556	320	N
1,1,2-Trichloroethane *	79005	11	C
Trichloroethylene (TCE)*	79016	58	C
Trichlorofluoromethane	75694	4600	N
2,4,6-Trichlorophenol	88062	58	C
2,4,5-Trichlorophenol	95954	1560	N
2-(2,4,5-Trichlorophenoxy)propionic acid	93721	126	N
2,4,5-Trichlorophenoxyacetic acid	93765	156	N
1,1,2-Trichloropropane	598776	78	N
1,2,3-Trichloropropane *	96184	0.091	C
1,3,5-Trinitrobenzene	99354	0.78	N
Vanadium pentoxide	1314621	140	N
Vinyl acetate	108054	15600	N
Vinyl chloride	75014	0.34	C
Xylene (mixed)	1330207	32000	N
Zinc	7440666	4600	N
Zinc phosphide	1314847	4.6	N

- 1 - Adapted from USEPA Region III Risk Based Concentration Table, except as noted.
- 2 - The RG is 1 ppm from 0-10 inches and 10 ppm below 10 inches.
- C - The RG is based on the carcinogenic endpoint and corresponds to an excess lifetime cancer risk of 1 in 1,000,000.
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SUPERFUND SECTION

Ground-Water Regions of the United States

By RALPH C. HEATH

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 2242

UNITED STATES DEPARTMENT OF THE INTERIOR
WILLIAM P. CLARK, Secretary

GEOLOGICAL SURVEY
Dallas L. Peck, Director



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reservoir for the bedrock.

The Glaciated Central region and the Northeast and Superior Uplands region are similar in that the unconsolidated material in both consists of glacial deposits. However, the bedrock in the two regions is different. The bedrock in the Glaciated Central region, as we have already seen, consists of consolidated sedimentary rocks that contain both steeply dipping fractures and fractures along bedding planes. In the Northeast and Superior

Uplands, on the other hand, the bedrock is composed of intrusive igneous and metamorphic rocks (nonbedded) in which most water-bearing openings are steeply-dipping fractures. As a result of the differences in fractures, the bedrock in the Glaciated Central region is, in general, a more productive and more important source of ground water than the bedrock in the Northeast and Superior Uplands region.

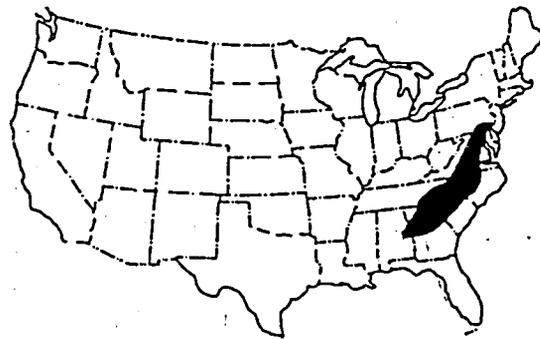
8. PIEDMONT BLUE RIDGE REGION

(Thick regolith over fractured crystalline and metamorphosed sedimentary rocks)

The Piedmont and Blue Ridge region is an area of about 247,000 km² extending from Alabama on the south to Pennsylvania on the north. The Piedmont part of the region consists of low, rounded hills and long, rolling, northeast-southwest trending ridges whose summits range from about a hundred meters above sea level along its eastern boundary with the Coastal Plain to 500 to 600 m along its boundary with the Blue Ridge area to the west. The Blue Ridge is mountainous and includes the highest peaks east of the Mississippi. The mountains, some of which reach altitudes of more than 2,000 m, have smooth-rounded outlines and are bordered by well-graded streams flowing in relatively narrow valleys.

The Piedmont and Blue Ridge region is underlain by bedrock of Precambrian and Paleozoic age consisting of igneous and metamorphosed igneous and sedimentary rocks. These include granite, gneiss, schist, quartzite, slate, marble, and phyllite. The land surface in the Piedmont and Blue Ridge is underlain by clay-rich, unconsolidated material derived from in situ weathering of the underlying bedrock. This material, which averages about 10 to 20 m in thickness and may be as much as 100 m thick on some ridges, is referred to as saprolite. In many valleys, especially those of larger streams, flood plains are underlain by thin, moderately well-sorted alluvium deposited by the streams. When the distinction between saprolite and alluvium is not important, the term regolith is used to refer to the layer of unconsolidated deposits.

The regolith contains water in pore spaces between rock particles. The bedrock, on the other hand, does not have any significant intergranular porosity. It contains water, instead, in sheetlike openings formed along fractures (that is, breaks in the otherwise "solid" rock) (fig. 36). The hydraulic conductivities of the regolith and the bedrock are similar and range from about 0.001 to 1 m



day⁻¹. The major difference in their water-bearing characteristics is their porosities, that of regolith being about 20 to 30 percent and that of the bedrock about 0.01 to 2 percent (fig. 37). Small supplies of water adequate for domestic needs can be obtained from the regolith through large-diameter bored or dug wells. However, most wells, especially those where moderate supplies of water are needed, are relatively small in diameter and are cased through the regolith and finished with open holes in the bedrock. Although, as noted, the hydraulic conductivity of the bedrock is similar to that of the regolith, bedrock wells generally have much larger yields than regolith wells because, being deeper, they have a much larger available drawdown.

All ground-water systems function both as reservoirs that store water and as pipelines (or conduits) that transmit water from recharge areas to discharge areas. The yield of bedrock wells in the Piedmont and Blue Ridge region depends on the number and size of fractures penetrated by the open hole and on the replenishment of the fractures by seepage into them from the overlying regolith. Thus, the ground-water system in this region can be viewed, from the standpoint of ground-water development, as a terrane in which the reservoir and pipeline functions are effectively separated. Because of its larger porosity, the regolith functions as a reservoir which slowly feeds water downward into the fractures in

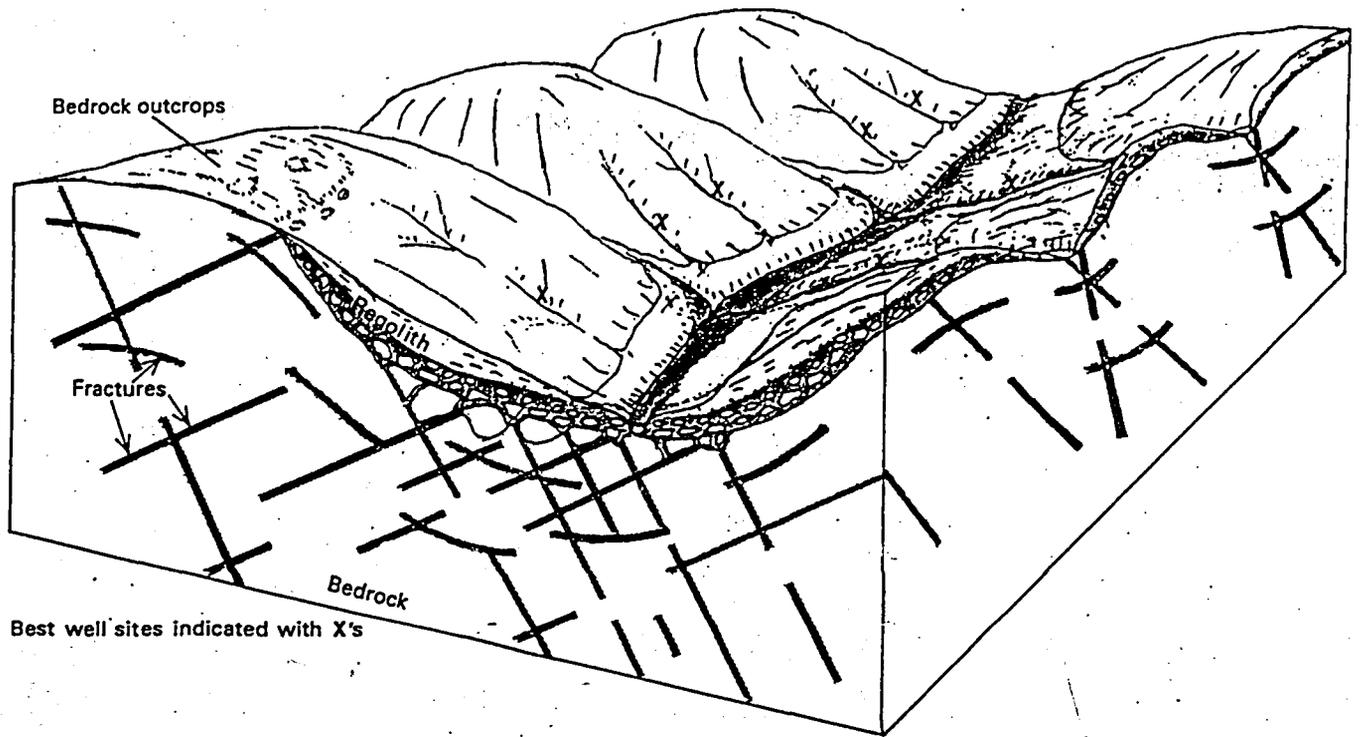


Figure 36. Topographic and geologic features of the Piedmont and Blue Ridge region.

the bedrock. The fractures serve as an intricate interconnected network of pipelines that transmit water either to springs or streams or to wells (fig. 38).

Recharge of the ground-water system occurs on the areas above the flood plains of streams, and natural discharge occurs as seepage springs that are common near the bases of slopes and as seepage into streams. With respect to recharge conditions, it is important to note that forested areas, which include most of the Blue Ridge and much of the Piedmont, have thick and very permeable soils overlain by a thick layer of forest litter. In these areas, even on steep slopes, most of the precipitation seeps into the soil zone, and most of this moves laterally through the soil in a thin, temporary, saturated zone to surface depressions or streams to discharge. The remainder seeps into the regolith below the soil zone, and much of this ultimately seeps into the underlying bedrock.

Because the yield of bedrock wells depends on the number of fractures penetrated by the wells, the key element in selecting well sites is recognizing the relation between the present surface topography and the location of fractures in the bedrock. Most of the valleys, draws, and other surface depressions indicate the presence of more intensely fractured zones in the bedrock which are more susceptible to weathering and erosion than are the intervening areas. Because fractures in the bedrock are the principal avenues along which ground water moves, the best well sites appear to be in draws on the sides of the

valleys of perennial streams where the bordering ridges are underlain by substantial thicknesses of regolith (fig. 36). Wells located at such sites seem to be most effective in penetrating open water-bearing fractures and in intercepting ground water draining from the regolith. Chan-

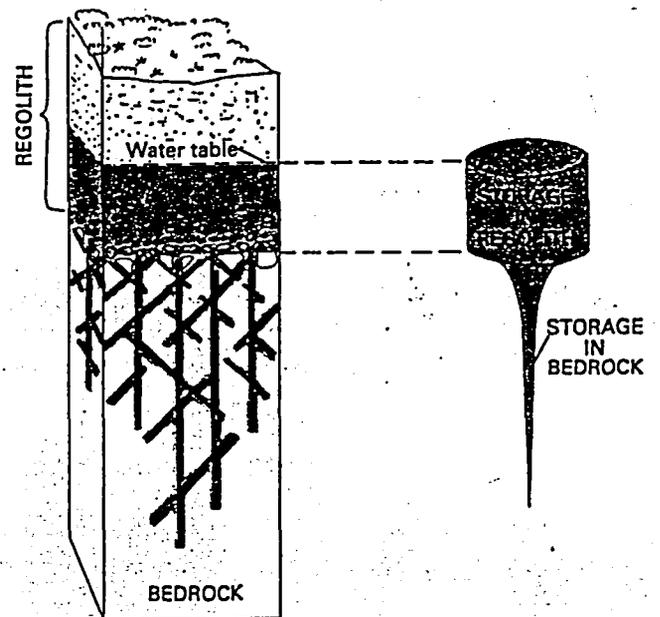


Figure 37. Differences in storage capacity of regolith and bedrock.

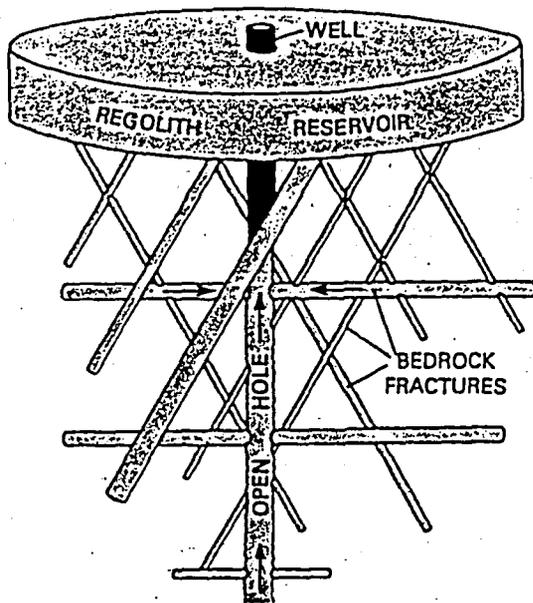


Figure 38. Separation of the storage and pipeline functions in the Piedmont and Blue Ridge region.

9. NORTHEAST AND SUPERIOR UPLANDS

(Glacial deposits over fractured crystalline rocks)

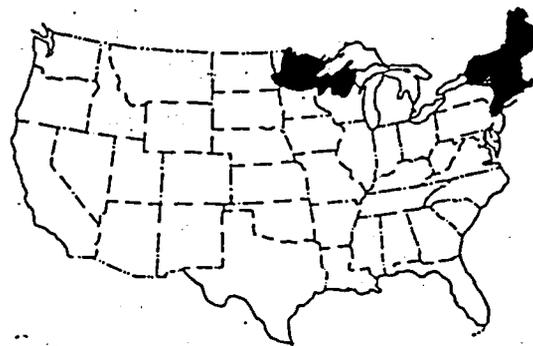
The Northeast and Superior Uplands region is made up of two separate areas totaling about 415,000 km². The Northeast Upland encompasses the Adirondack Mountains, the Lake Champlain valley, and nearly all of New England. The parts of New England not included are the Cape Cod area and nearby islands, which are included in the Atlantic and Gulf Coastal Plain region, and the Triassic lowland along the Connecticut River in Connecticut and Massachusetts, which is included in the Glaciated Central region. The Superior Upland encompasses most of the northern parts of Minnesota and Wisconsin adjacent to the western end of Lake Superior. The Northeast and Superior Uplands are characterized by rolling hills and low mountains. Land-surface altitudes in the Northeast Upland range from sea level to more than 1,500 m on some of the peaks in the Adirondacks and White Mountains. In contrast to the mountainous areas in the Northeast, the Superior Upland is in an area of rolling hills whose summits reach altitudes of only 300 to 600 m.

Bedrock in the region ranges in age from Precambrian to Paleozoic and consists mostly of granite, syenite,

ces of success seem to be somewhat less for wells on the flood plains of perennial streams, possibly because the alluvium obscures the topographic expression of bedrock fractures. The poorest sites for wells are on the tops of ridges and mountains where the regolith cover is thin or absent and the bedrock is sparsely fractured.

As a general rule, fractures near the bedrock surface are most numerous and have the largest openings, so that the yield of most wells is not increased by drilling to depths greater than about 100 m. Exceptions to this occur in Georgia and some other areas where water-bearing, low-angle faults or fractured zones are present at depths as great as 200 to 300 m.

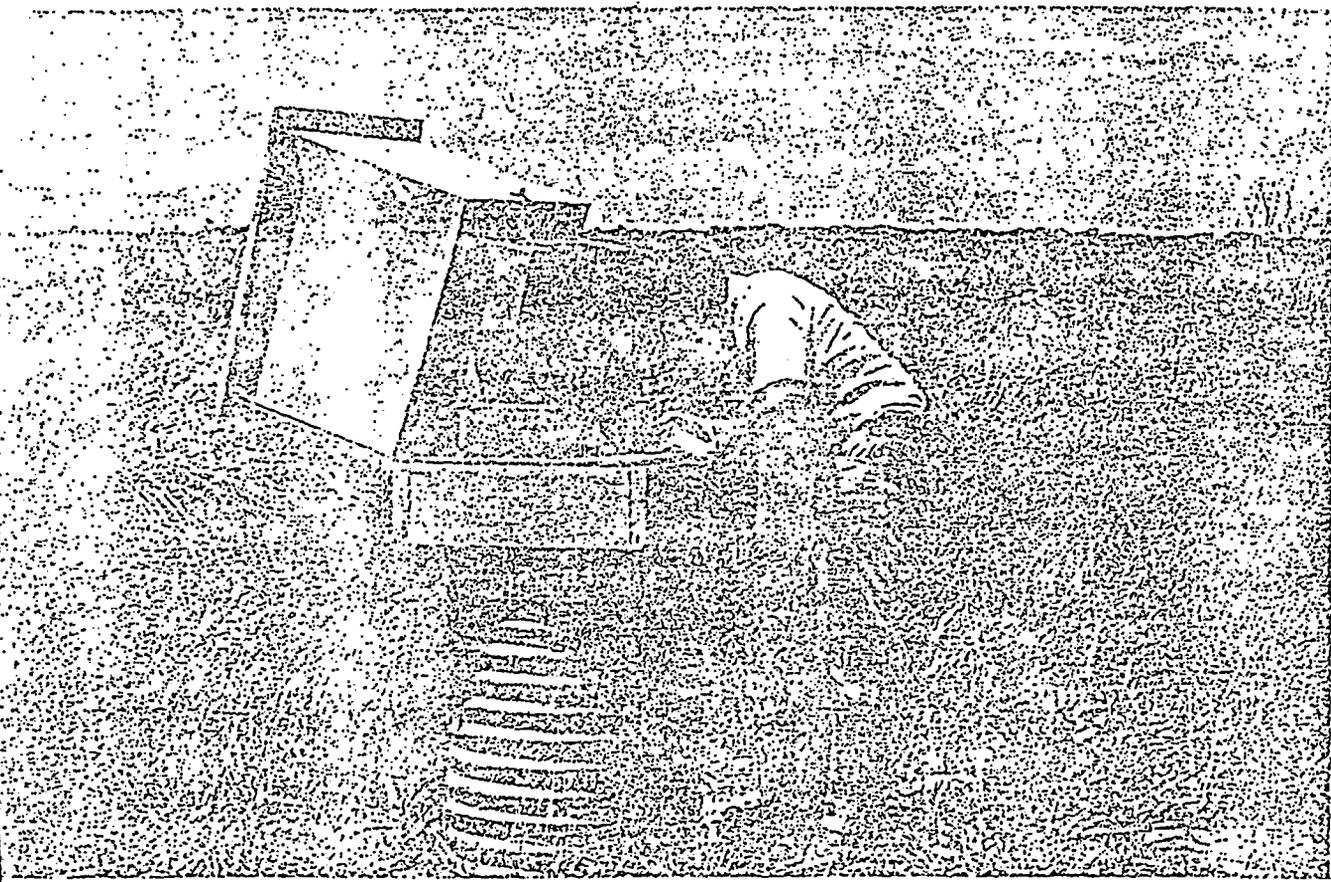
The Piedmont and Blue Ridge region has long been known as an area generally unfavorable for groundwater development. This reputation seems to have resulted both from the small reported yields of the numerous domestic wells in use in the region that were, generally, sited as a matter of convenience and from a failure to apply existing technology to the careful selection of well sites where moderate yields are needed. As water needs in the region increase and as reservoir sites on streams become increasingly more difficult to obtain, it will be necessary to make more intensive use of groundwater.



anorthosite, and other intrusive igneous rocks and metamorphosed sedimentary rocks consisting of gneiss, schist, quartzite, slate, and marble (fig. 39). Most of the igneous and metamorphosed sedimentary rocks have been intensely folded and cut by numerous faults.

The bedrock is overlain by unconsolidated deposits laid down by ice sheets that covered the areas one or more times during the Pleistocene (fig. 40) and by gravel, sand, silt, and clay laid down by meltwater streams and in lakes that formed during the melting of the ice (fig. 39). The thickness of the glacial deposits ranges from a few meters on the higher mountains, which also have large expanses of barren rock, to more than 100 m in some valleys. The most extensive glacial deposit is till, which was laid down

Basic Elements of Ground-Water Hydrology with Reference to Conditions in North Carolina



U.S. GEOLOGICAL SURVEY
WATER RESOURCES INVESTIGATIONS
OPEN-FILE REPORT 80-44

Prepared in cooperation with the
North Carolina Department of Natural
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GEOLOGICAL SURVEY

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With Reference to Conditions in North Carolina

By *Ralph C. Heath*

U.S. Geological Survey
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1980

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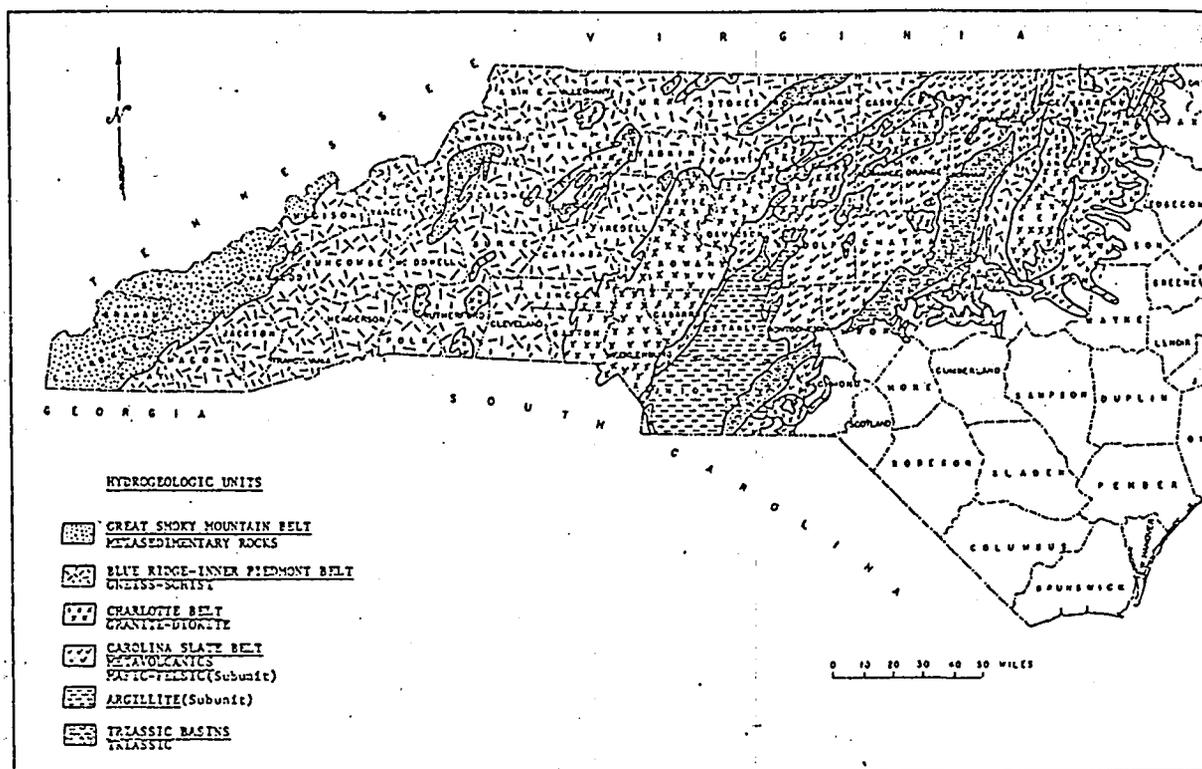
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Rock Units and Aquifers in the Piedmont and Mountains



The rocks underlying the Piedmont and mountains can be divided into two groups: (1) bedrock, and (2) saprolite (or residuum). The saprolite underlies the land surface and ranges in thickness from a foot or two near bedrock outcrops to more than 100 ft. Bedrock underlies the saprolite and is the parent rock from which the saprolite was derived in the process referred to as weathering.

Many stream valleys, especially those of larger streams, are underlain by a layer of material similar in composition to saprolite. This material, which has been deposited by the streams during floods, is correctly referred to as *alluvium*. However, to avoid unnecessary complications, we will lump the alluvium in with the saprolite for the purpose of this discussion.

The bedrock underlying the Piedmont and mountains consists of many different types of igneous and metamorphosed igneous and sedimentary rocks. The Generalized Geological Map of North Carolina accompanying the discussion of WATER-BEARING ROCKS divides the bedrock in the Piedmont and

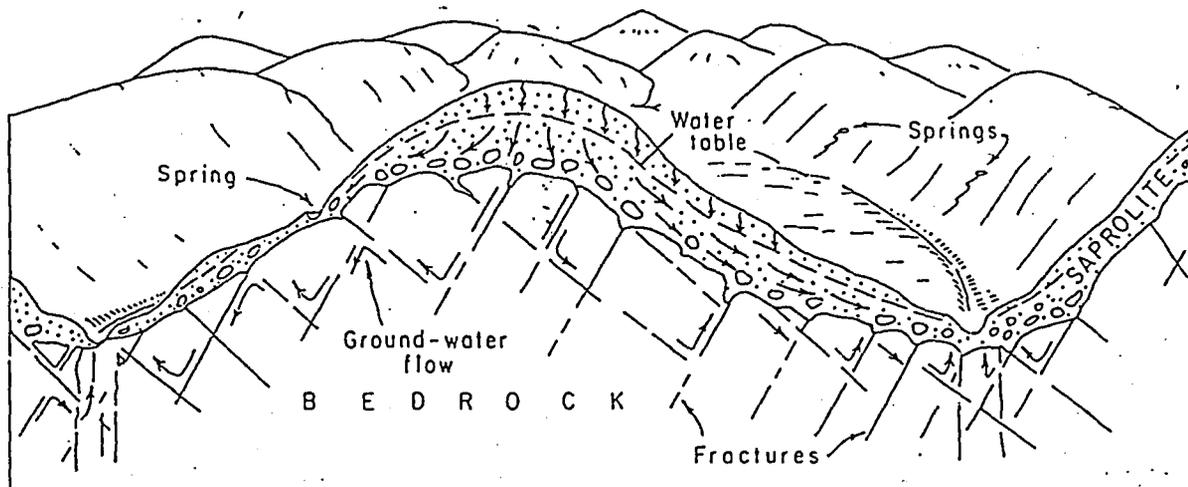
mountains into six units. The 1:500,000 scale Geologic Map of North Carolina, published in 1958, divides the bedrock in the same area into 48 different units. But, a much larger number of units have been identified and are shown on large scale geologic maps.

The bedrock units differ from each other in mineral composition and other geologic characteristics. Fortunately, these differences do not result in large differences in hydraulic characteristics so that it is possible to combine the bedrock units into a relatively small number of hydrogeologic units.

The accompanying map shows the hydrogeologic units into which the bedrock in the Piedmont and mountains has been divided by the U.S. Geological Survey and the North Carolina Groundwater Section.

The most productive hydrogeologic units are the Great Smoky Mountain belt and the Blue Ridge-Inner Piedmont belt. The least productive units are the Carolina Slate Belt and the Triassic Basins. The Charlotte Belt is intermediate in productivity.

Ground-Water Situation in the Piedmont and Mountains



The *saprolite* (weathered rock) that forms the land surface in the Piedmont and mountains consists of unconsolidated granular material. It thus contains water in the pore spaces between rock particles.

The *bedrock*, on the other hand, does not have any significant intergranular (primary) porosity. It contains water, instead, in sheet-like openings formed along fractures (that is, breaks in the otherwise "solid" rock). Fractures in bedrock are of two types: (1) *joints*, which are breaks along which there has been no differential movement; and (2) *faults*, which are breaks along which the adjacent rocks have undergone differential movement.

Faults are formed during earthquakes and generally contain larger and more extensive openings than those developed along joints. Joints, however, are far more numerous than faults.

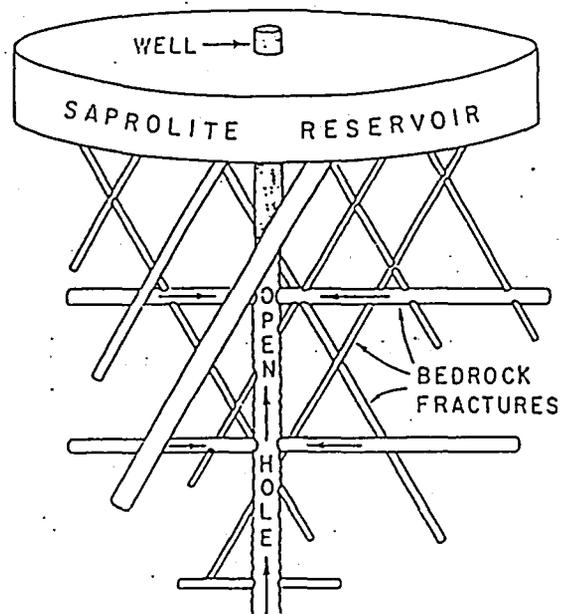
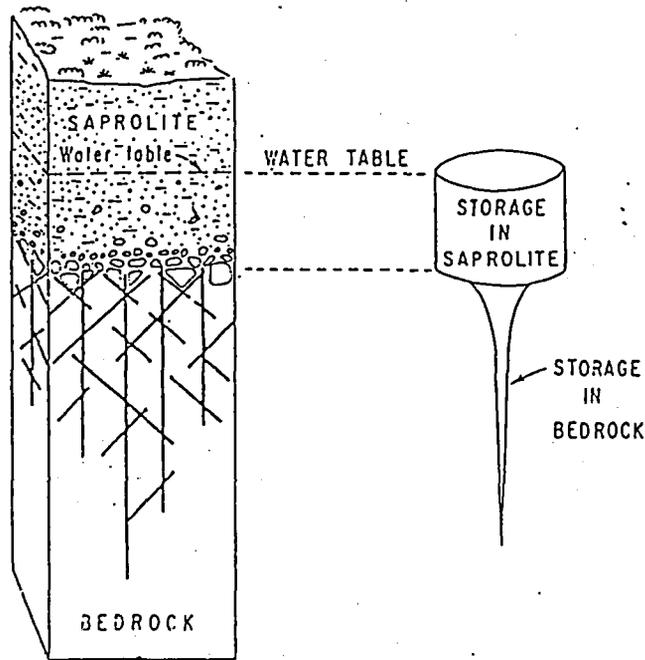
Fractures (joints and faults) are more abundant under valleys, draws, and other surface depressions than under hills. In fact,

geologists assume that it is the presence of fractures that determined the position of valleys in the first place. Fractures tend to be more closely-spaced and the openings developed along them tend to be larger near the surface of the bedrock. Most fractures appear to be non water-bearing below a depth of 300 to 400 ft. Large water-bearing openings, penetrated below this depth are probably associated with faults.

The ground-water system in the Piedmont and mountains is recharged by precipitation on the interstream areas. A part of the precipitation infiltrates through the unsaturated zone to the water table, which normally occurs in the saprolite.

Ground water moves laterally and downward through the saprolite to points of ground-water seepage (springs) on the hillsides and to the streams in the adjacent valleys. Some of the water in the saprolite also moves downward into the bedrock and, thereafter, through the fractures to the adjacent valleys.

Hydraulic Characteristics of the Piedmont and Mountain Ground-Water System



One of the most basic concepts of ground-water hydrology is that aquifers function both as reservoirs, in which water is in storage, and as pipelines, which transmit water from one point to another. This is referred to as the *reservoir-pipeline concept*. This concept forms a useful basis on which to discuss the hydraulic characteristics of the Piedmont and mountain ground-water system.

The reservoir (storage) function of aquifers depends on the porosity. The pipeline function depends on the hydraulic conductivity and the thickness of the aquifer. The approximate range in porosity and hydraulic conductivity for the sapolite and bedrock is shown in the following table.

Rock type	Porosity in percent	Hydraulic conductivity in feet per day
Sapolite	20-30	1-20
Bedrock	0.1-1	1-20

The above values suggest that the principal difference between sapolite and bedrock is in water-storage capacity. In other words, the sapolite has the capacity to store a much larger quantity of water than does the bedrock. This is not the entire story, however.

As we noted above, the capacity of an aquifer to transmit water depends both on hydraulic conductivity and on aquifer thickness. The part of the bedrock containing water-bearing fractures is several times thicker than the sapolite.

We can then, without great error, view the ground-water system in the Piedmont and mountains as consisting of a saprolite reservoir overlying a bedrock pipeline consisting of numerous small, interconnected pipes. In the vicinity of a pumping well the bedrock fractures ("pipes") convey water from the saprolite reservoir to the well.

The yield of a well drawing from fractured bedrock depends on several factors. The most important of these are believed to be:

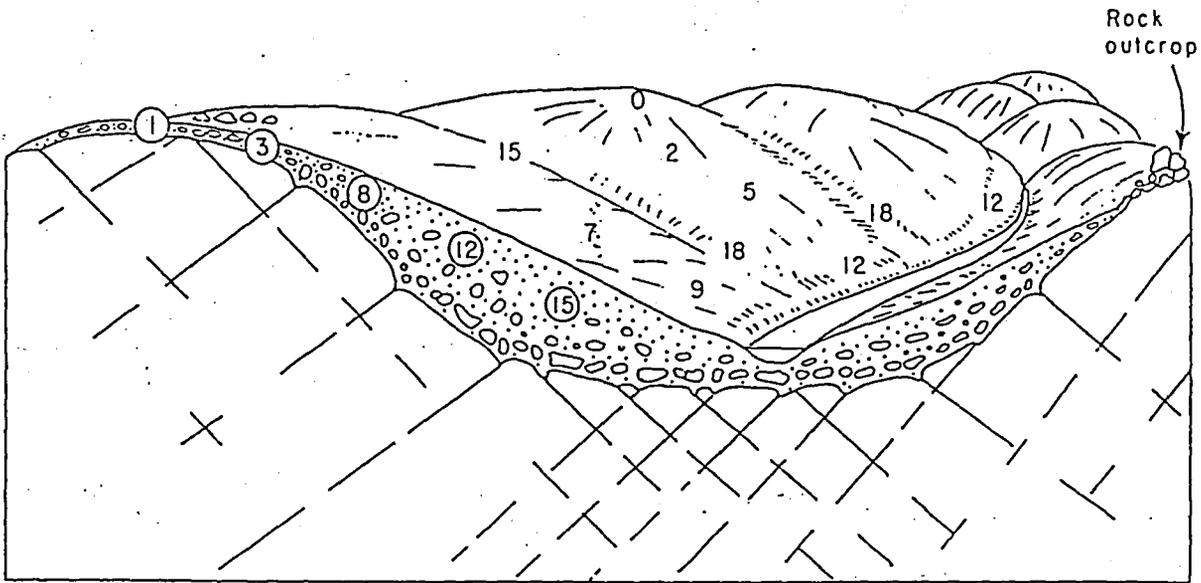
1. The number, size, areal extent, and degree of interconnection of the fractures penetrated by the well,
2. The thickness of saturated saprolite in the vicinity of the well and the specific yield of the saprolite, and

3. The hydraulic conductivity of the saprolite and the nature of the hydraulic connection between the saprolite and the bedrock.

The number and the size of the fractures control the rate at which water can enter the well. The areal extent and degree of interconnection of the fractures control the size of the area that supplies water to the well.

The thickness and the specific yield of the saprolite determines the volume of water available from storage in the saprolite. The hydraulic conductivity of the saprolite and the nature of the hydraulic connection between the saprolite and the bedrock determines the rate at which water can drain from the saprolite into the bedrock fractures.

Selecting Well Sites in the Piedmont and Mountains



- 5 Number related to topographic position
- ⑧ Number related to saprolite thickness

Most ground-water supplies in the Piedmont and mountains are obtained from wells that are cased through the saprolite and finished with open holes in the bedrock. The yield of these wells depends on the number and size of the fractures they penetrate. Therefore, where moderate to large supplies of water are needed, well sites should be selected at the places where fractures appear to be most abundant.

H. E. LeGrand, of the U.S. Geological

Survey, attempted in 1967 to indicate the relative favorability of well sites in the Piedmont and mountains by assigning point values to areas on the basis of saprolite thickness and topographic position. The point values assigned by LeGrand to features of the land surface that suggest thickness of saprolite and to different topographic positions are shown below. Selected values of each are also indicated on the above sketch.

GW-2-

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MONROE AREA, NORTH CAROLINA

Division of Ground Water

GROUND-WATER BULLETIN NUMBER 5

NORTH CAROLINA
DEPARTMENT OF WATER RESOURCES



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**GEOLOGY AND GROUND-WATER
RESOURCES**

of the
MONROE AREA, NORTH CAROLINA

BY EDWIN O. FLOYD

GROUND-WATER BULLETIN NUMBER 5

**NORTH CAROLINA
DEPARTMENT OF WATER RESOURCES**

WALTER E. FULLER, *Director*

DIVISION OF GROUND WATER

HARRY M. PEEK, *Chief*

Prepared By The Geological Survey
United States Department Of The Interior
In Cooperation With The
North Carolina Department Of Water Resources

RALEIGH

1965

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Geology and Ground-Water Resources of the Monroe Area, North Carolina

By

EDWIN O. FLOYD

ABSTRACT

The Monroe area includes Anson, Stanly, and Union Counties in the south-central part of North Carolina. It has an area of 1,575 square miles and had a population of 109,746 in 1960. The economy is both agricultural and industrial.

The area consists mainly of low rounded hills with gentle slopes in the southeastern part of the Piedmont province. The altitude of land surface ranges from about 150 feet to 936 feet above mean sea level, and the land surface slopes generally toward the southeast.

The surface is underlain mainly by metamorphic and igneous rocks, chiefly tuffaceous argillite, laminated argillite, tuff, phyllite, gneiss, granite, and diorite-gabbro. A belt of Triassic rocks in Anson County contains sandstone, shale, and other sedimentary rocks.

The tuffaceous argillite is the chief aquifer of the area because it has a relatively high permeability and wide areal extent. The yield of individual wells in this aquifer averages about 13 gpm (gallons per minute), and may be as much as 200 gpm.

The yield of wells in the area is related to topography. The average yield of wells on hills is about half the average yield of wells in valleys. The majority of the wells in this area are drilled on upland sites where conditions are unfavorable for obtaining more than 5 to 10 gpm from a well.

Generally, the yield of wells is determined by the secondary permeability of the rocks, which decreases with depth. There is usually little increase in the yield of wells below a depth of about 250 feet.

The present utilization of ground water in the area is only a fraction of that available from the aquifers. Recharge and discharge are apparently in natural balance because there is no evidence of perennial lowering of the water table.

Topography

The Monroe area lies within the upland section of the Piedmont physiographic province, which is an uplifted, submaturely to maturely dissected peneplane.

The sedimentary rocks in the area strike generally northeast-southwest. The igneous intrusives are generally elongated and strike northeast-southwest. The relative resistance of different rock types to erosion controls the topographic expression in the area.

Average altitude of the upland surface ranges from about 150 feet above mean sea level in the southeastern part of Anson County to about 800 feet in western Stanly County. The highest altitudes of the area are in northwestern Stanly County, in the Uwharrie Mountain range. The highest of these hills is Morrow Mountain, which has an elevation of 936 feet above mean sea level.

Drainage

The area is drained by the Pee Dee and the Wateree Rivers and their tributaries. Most of Anson County is drained to the north by the Rocky River, which flows into the Pee Dee River, or to the east by the Pee Dee River, which forms the eastern border of the county. A small part of southwestern Anson County is drained to the south by several small streams that empty into the Great Pee Dee River in South Carolina. The southern part of Stanly County is drained by the Rocky River, which flows along its southern boundary. Most of the eastern part of the county is drained into Badin Lake, the Pee Dee River, and Lake Tiller, which forms the eastern boundary of Stanly County. About three-fourths of Union County is drained in a northeasterly direction to the Rocky River. Approximately 20 percent of the county, the southwestern part, is drained to the southwest into the Wateree River in South Carolina. The remainder is drained to the south into Lynches River, which empties into the Great Pee Dee River in South Carolina. The courses of the individual streams within the area are diverse, and the drainage pattern is largely controlled by the geology of the area.

GEOLOGY

Introduction

During the fall and winter of 1961-62 a reconnaissance survey was made of the geology in the area. With the exception of the mapping of the Albemarle quadrangle (Conley, J. F., 1962), little geologic mapping in the area had been done prior to this time. The existing geologic maps were inadequate for the purposes of this investigation; therefore, reconnaissance geologic mapping was a necessary part of the project work. (See fig. 7, 9, 11). The rock units shown on the maps are generalized in some cases and usually contain more than one type of rock. The different rock types were grouped into mappable units on the basis of similarity in age, petrology, or water-bearing properties. They are discussed in the following section in the same order as they appear on the geologic maps.

Area Distribution and Character of Rock Units Sands and clays of Quaternary age

Sand and gravel of Quaternary age are considered generally to be the youngest geologic unit in the area. The unit occurs at elevations ranging from about 400 feet above mean sea level in the vicinity of Lilesville to about 250 feet east of Morven. Outcrops are in isolated patches and pockets of various size throughout the southeastern part of Anson County. The unit consists of varicolored, laminated, crossbedded, kaolinitic sands and clays and deposits of well-rounded stream gravels, all apparently of continental origin. The gravels of this unit range from pea size to small boulder size. The thickness of the deposits ranges from a feather edge to more than 50 feet. Excellent exposures of this unit can be seen along Highway 74 about 3.5 miles east of Lilesville and, in the same vicinity, in a commercial gravel pit where the gravel is mined for road metal.

Triassic (Newark Group)

Rocks of the Newark Group were named for Triassic exposures near Newark, New Jersey. In 1875, W. C. Kerr (1875) correlated these rocks with the triassic exposures in North Carolina. Three formations are distinguishable within the Newark Group (Campbell, M. R., and Kimball, K. W., 1923). In descend-

centration of greater than 3.0 ppm is generally considered to indicate the presence of a source of pollution. Dug wells and improperly cased wells are most subject to nitrate pollution by infiltration of surface water.

The presence of small seams of coal and other organic material in the Triassic rocks may be the cause of higher than normal nitrate concentrations in water samples from three wells in Anson County.

Hardness

Hardness is the property of water attributable to the presence of dissolved alkaline elements, and is expressed in analyses as equivalent calcium carbonate (CaCO_3). Calcium, magnesium, and other polyvalent cations are responsible for the hardness of water. Hard water is objectionable because of its soap-consuming properties and because it forms scale in boilers and containers in which it is heated. The hardness of water samples from the Monroe area ranged from 8 to 1,160 ppm. The harder waters were from Triassic rocks.

The U. S. Geological Survey classifies water with respect to hardness as follows:

<i>Hardness as CaCO_3, (ppm)</i>	<i>Classification</i>
0-60	Soft water
61-120	Moderately hard water
121-180	Hard water
181+	Very hard water

ROCK UNITS AND THEIR WATER-BEARING PROPERTIES

Introduction

There are seven principal water-bearing rock units in the Monroe area. Tables are presented and discussed to allow comparison of the water-bearing properties of the various rock units and to illustrate the effects of well depth and topographic location on the yield of wells in the Monroe area.

The comparisons discussed in this section are believed to be representative of the rock units mentioned. However, comparisons based on such a small number of wells cannot be considered highly accurate, mathematically.

Table 1. Average Yield of Wells According to Rock Type.

	No. of wells	Average depth (feet)	Yield (gallons per minute)		
			Range	Average	Per foot of well
All Wells	407	120	4-200	14	0.11
Rock unit					
Sand (Quaternary)	2	28	5	5	0.18
Sandstone (Triassic)	26	156	3/4-65	16	0.10
Granite	15	95	1-100	18	0.19
Phyllite and mica schist	5	236	2 1/2-90	37	0.16
Tuffaceous argillite	302	119	4-200	13	0.11
Laminated argillite	39	113	1 1/2-75	15	0.13
Lower volcanic unit	18	128	1-60	12	0.09

Relative Water-Bearing Properties of the Rock Units

Data on depth and yield were compiled for 407 wells in the Monroe area. Table 1 shows the average yield per well and per foot of well for both the total number of wells and the number of wells in each rock unit.

As shown by the data in Table 1, the 407 wells inventoried in the Monroe area have an average depth of about 120 feet, an average yield per well of about 14 gpm, and an average yield per foot of well of 0.11 gallons per minute (gpm).

Comparison of the average yield values in Table 1 indicates that the highest average yield per well is obtained from wells in the phyllite and mica schist unit and that the lowest average yield per well is obtained from wells in Quaternary sand. The highest yield per foot of well is obtained from wells in the granite unit and the lowest yield per foot of well is obtained from wells in the lower volcanic unit.

Sands and Clays of Quaternary Age

The sand and clay unit of Quaternary age covers most of the southeastern part of Anson County. It consists of interbedded kaolinitic sands and clays and well-rounded stream gravel. The gravel ranges from pea-size to large cobbles. The thickness of

miles. The unit contains several types of related rocks, the most common of which are interbedded felsic and mafic tuffaceous argillites, fine-grained tuffs, breccias, and flows. The tuffaceous argillites are overlain in some areas by graywacke sandstones and siltstones with some interbedded mafic tuffs, breccias, and conglomerates. The rocks of this unit are largely made up of fine ash and other volcanic ejecta which were deposited in water with very little reworking and sorting.

Because of its areal extent, the tuffaceous argillite unit is the most important aquifer in the Monroe area. The movement of ground water in this unit is along cleavage planes, bedding planes, joints, and quartz veins.

Adequate supplies for small municipal and industrial users as well as domestic users are available in all parts of the unit. Data collected on 304 wells in this unit indicate that yields of up to 200 gpm may be expected and that the yield per foot ratio decreases below a depth of about 150 feet.

Topographic location is also an important factor in selecting a well site in this unit. The best yields have been obtained from wells drilled in draws, valleys, and on slopes, respectively.

Table 5 illustrates the results of the tabulation of pertinent data for wells in the tuffaceous argillite unit.

Analyses of several water samples from this unit show that the water is generally hard and contains moderate amounts of iron. Apparently, much of the objectionable iron reported in the water by some well owners is secondary and is derived from rusting of the well casings and pipes in the water systems.

Table 5. Average Yield of Wells in Tuffaceous Argillite

According to depth					
Range in depth (feet)	No. of wells	Average depth (feet)	Yield (gallons per minute)		
			Range	Average	Per foot of well
0-100	148	75	½-90	12	0.15
101-150	91	118	½-100	12	0.11
151-200	41	180	¾-90	13	0.07
201-250	6	235	1½-15	6	0.03
251-300	11	278	1-30	5	0.02
Greater than 300	7	353	½-200	68	0.19
All wells	304	119	½-200	13	0.11

According to topographic location					
Topographic location	No. of wells	Average depth (feet)	Yield (gallons per minute)		
			Range	Average	Per foot of well
Hill	163	110	½-75	10	0.09
Flat	34	109	½-95	11	0.10
Slope	24	123	2-180	20	0.16
Draw	6	75	7½-90	29	0.39
Valley	7	194	5-200	46	0.24

Memorandum

DATE: May 28, 1999

TO: File

FROM: Scott C. Ryals
Environmental Chemist
NC Superfund Section

SUBJECT: City of Wadesboro Water Lines

Virginia Chemical Company
Wadesboro, Anson County, NC
EPA ID: NCS FNO 406 924

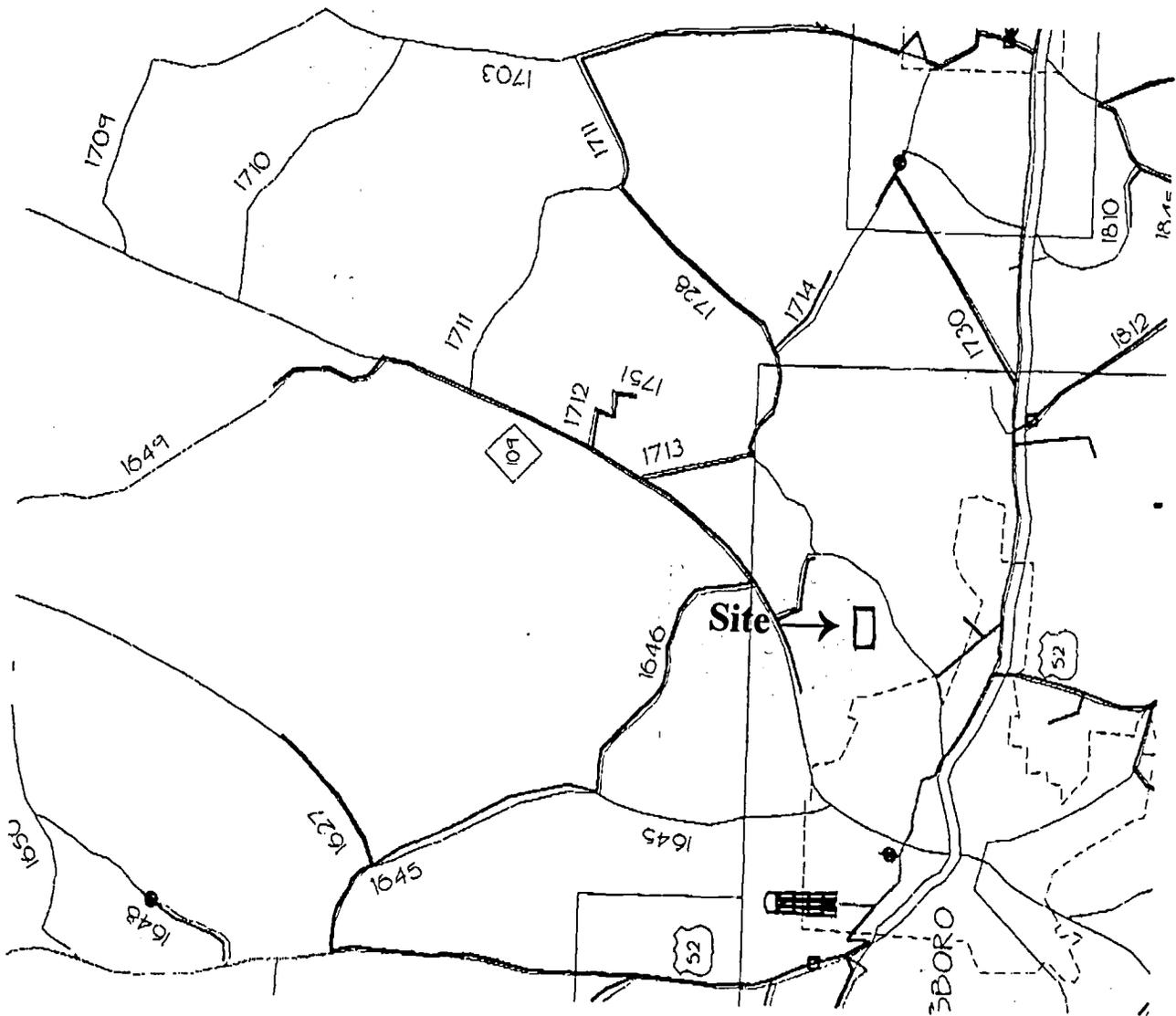
On May 27, 1999, Ms. Jeanette Stanley and myself conducted a site assessment of the subject property. During the investigation, we contacted Mr. Steve Natoli with the Wadesboro City Water Office. The attached document provides a graphical representation of the location of the city maintained water lines near the subject property. According to the information supplied by Mr. Natoli, the City of Wadesboro does not supply water to the residents in the vicinity of the subject site.

To Scott Kyals

Scott,

This may not work if your Fax Prints in black & white.
Since the water Lines are colored. Let me Know.

Steve



Memorandum

DATE: May 28, 1999

TO: File

FROM: Scott C. Ryals
Environmental Chemist
NC Superfund Section

SUBJECT: Anson County Water Lines

Virginia Chemical Company
Wadesboro, Anson County, NC
EPA ID: NCS FNO 406 924

On May 27, 1999, Ms. Jeanette Stanley and myself conducted a site assessment of the subject property. During the investigation, we contacted Mr. Hugh James with the Anson County Public Works Department. The attached document provides a graphical representation of the location of the county maintained water lines. Areas that are highlighted in yellow indicated that no county water lines are maintained. According to the information supplied by Mr. James, Anson County does not supply water to the residents in the vicinity of the subject site.

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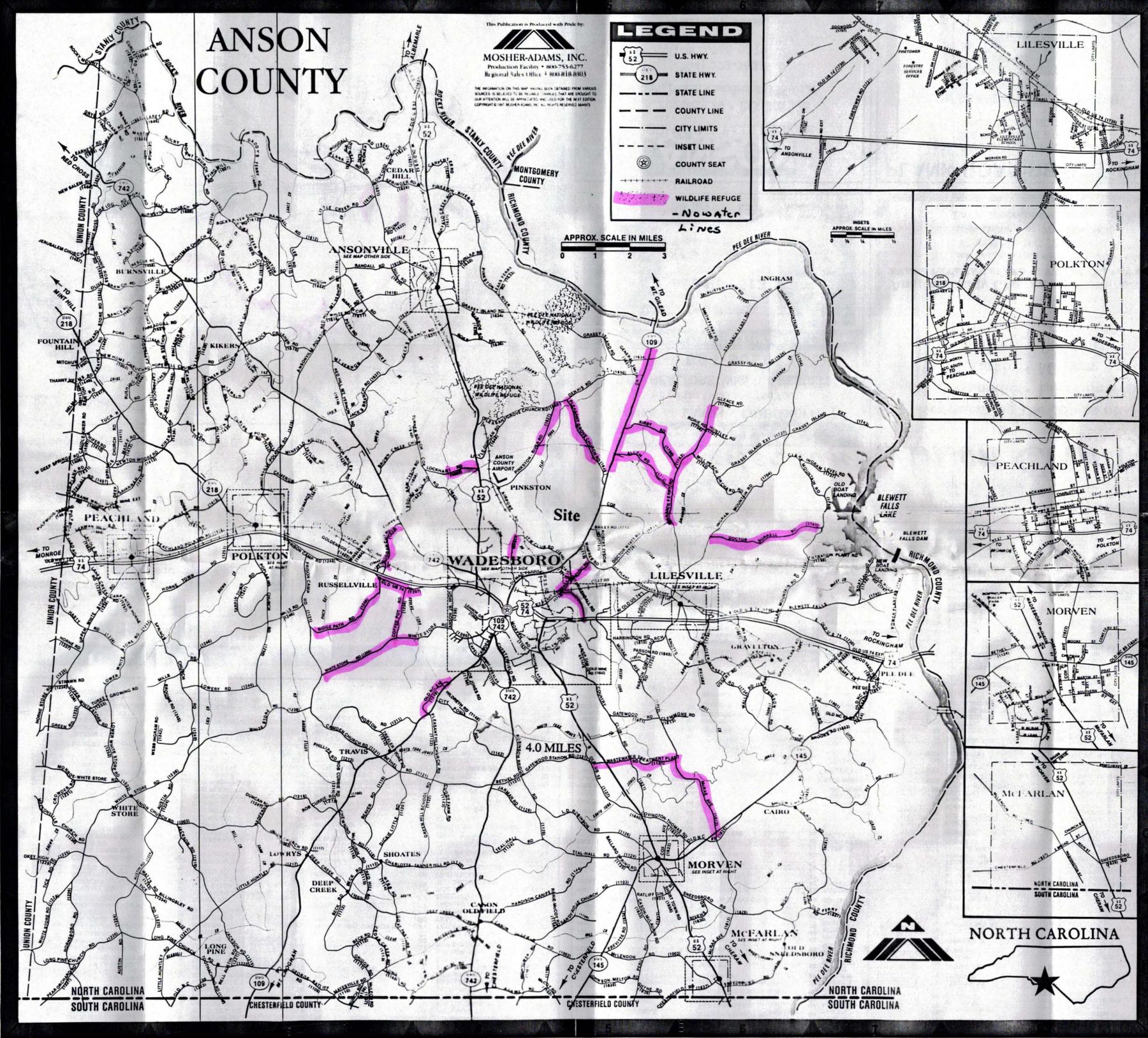
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MEMO

TO: Superfund Section Staff

FROM: Jeanette Stanley
Environmental Chemist
NC Superfund Section

DATE: April 23, 1999

SUBJECT: Update on Status of Wellhead Protection Programs in N.C.

I spoke with Mr. Gale Johnson, Public Water Supply (919) 715-2853 on April 13, 1999. He said that there are still no state-approved wellhead protection areas within North Carolina.

The two earliest applications will likely be the first ones approved. The Town of Black Mountain has defined an area, conducted an inventory, and submitted an application. A privately-owned public water system, JAARS, in Waxhaw, NC also submitted one of the two first applications. To date, fifteen applications have been received.

Mr. Johnson said that the lack of a state-approved wellhead protection area does not preclude a Public Water Supply system from setting their own set back (or protection) criteria, such as up to 1,000' from a hazardous waste disposal site and 500' from a UST.

Mr. Johnson suggested that if there is a question about whether or not a nearby public water supply has any set-back criteria, it is best to contact the operator directly.

CENSUS '90



1990 Census of
Population and Housing
Summary Population and
Housing Characteristics
North Carolina

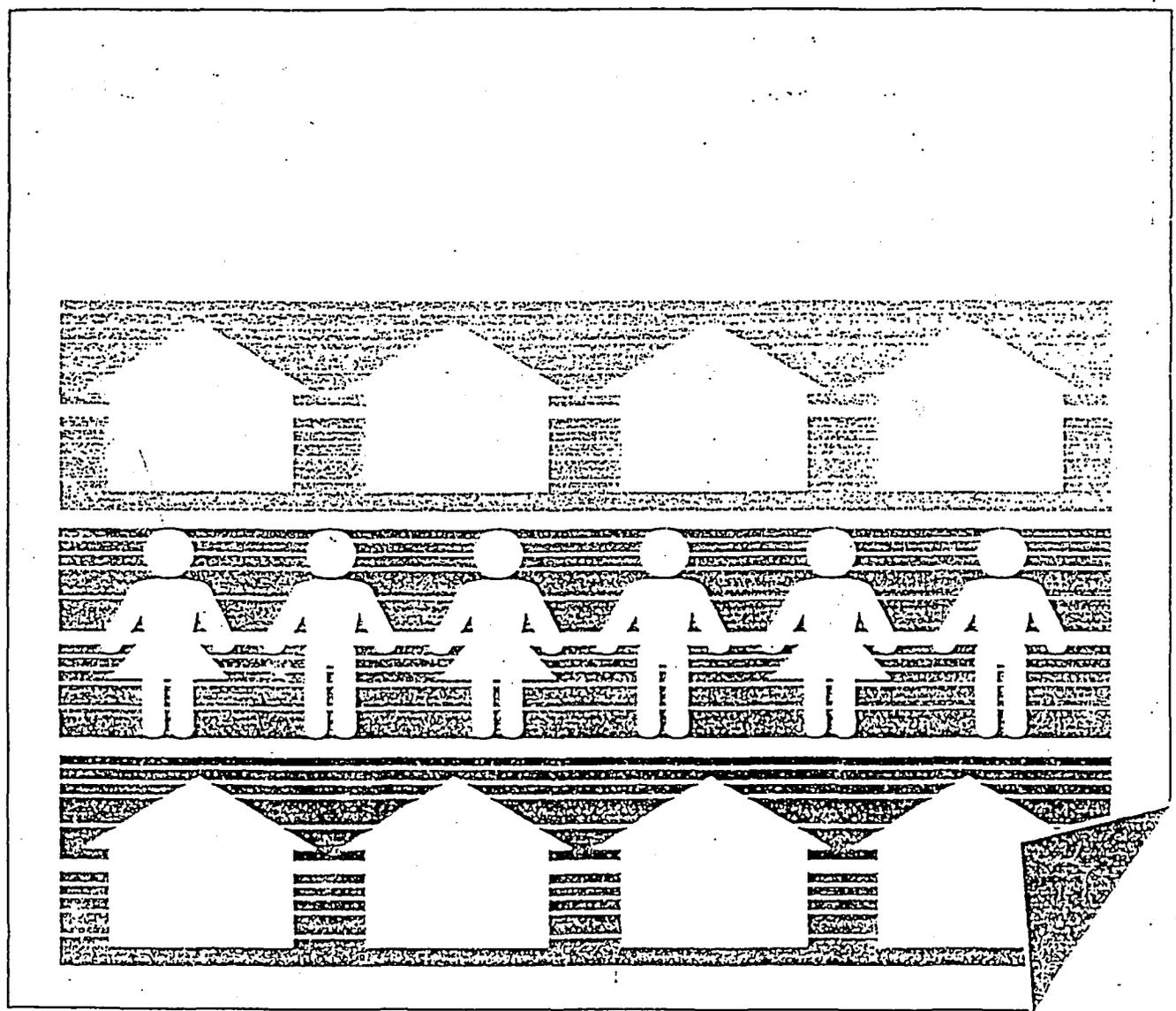


Table 5. Household, Family, and Group Quarters Characteristics: 1990

Definitions of terms and meanings of symbols see text.

County County Subdivision	Persons in households	All house- holds	Family households			Nonfamily households				Persons per—		Persons in group quarters			
			Total	Married- couple family	Female house- holder, no husband present	Householder living alone		Total	Total	Female	Household	Family	Total	Insti- tutional- ized persons	Other per- sons in group quarters
						65 years and over									
						Total	Female								
The State	404 167	2 517 026	1 812 053	1 424 206	309 876	705 973	596 959	226 384	182 329	2.54	3.03	224 470	83 400	141 070	
Alamance County	105 300	42 652	30 745	24 295	5 130	11 907	10 467	4 598	3 748	2.47	2.94	2 886	1 173	1 713	
Township 1, Patterson	2 800	1 078	847	715	94	231	215	115	86	2.60	2.98	-	-	-	
Township 2, Noble	3 200	1 274	994	871	85	280	254	106	63	2.54	2.92	-	-	-	
Alamance village	2 200	112	80	67	11	32	30	17	13	2.20	2.76	-	-	-	
Township 3, Boone Station	13 100	5 228	3 853	3 361	380	1 375	1 071	445	352	2.51	2.91	1 759	115	1 644	
Burlington city (pt.)	4 400	1 782	1 409	1 269	117	373	340	131	102	2.50	2.85	-	-	-	
Leon College town	2 700	1 066	683	581	77	383	213	77	58	2.59	3.00	1 637	12	1 625	
Simpsonville town (pt.)	1 400	583	404	324	65	179	126	43	32	2.54	3.00	-	-	-	
Glen Raven CDP (pt.)	1 200	513	406	345	40	107	95	63	52	2.53	2.86	-	-	-	
Township 4, Marion	4 400	1 650	1 340	1 114	173	310	289	127	97	2.73	3.08	-	-	-	
Altamaha-Osprey CDP	1 000	424	307	233	57	117	113	56	44	2.54	3.06	-	-	-	
Township 5, Faucette	3 000	1 135	937	815	93	198	178	84	69	2.65	2.95	-	-	-	
Township 6, Graham	10 000	7 645	5 631	4 408	988	2 214	1 963	837	709	2.41	2.87	450	443	7	
Burlington city (pt.)	6 000	2 472	1 821	1 451	291	651	587	210	177	2.46	2.87	18	18	-	
Graham city (pt.)	9 000	4 228	2 813	2 205	592	1 315	1 181	539	456	2.33	2.85	432	425	7	
How River town (pt.)	2 000	90	50	21	20	40	36	6	5	2.32	3.08	-	-	-	
Township 7, Albright	2 500	1 002	750	671	83	212	187	83	58	2.56	2.91	-	-	-	
Saxapahaw CDP (pt.)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Township 8, Newlin	3 200	1 269	980	858	90	289	264	118	95	2.60	3.02	-	-	-	
Saxapahaw CDP (pt.)	4 000	1 68	134	109	19	34	31	13	9	2.73	3.10	-	-	-	
Township 9, Thompson	4 700	1 781	1 382	1 116	203	399	339	125	100	2.67	3.07	49	44	5	
Saxapahaw CDP (pt.)	1 000	257	210	156	47	47	41	10	8	2.80	3.13	-	-	-	
Simpsonville CDP (pt.)	1 000	415	312	269	32	103	87	32	27	2.57	3.00	-	-	-	
Township 10, Melville	9 000	3 563	2 661	2 155	407	902	815	334	264	2.56	3.02	158	138	-	
Melville city (pt.)	4 000	1 697	1 229	939	251	463	432	196	165	2.51	3.01	10	10	-	
Simpsonville CDP (pt.)	2 000	51	46	44	2	5	5	2	2	2.53	2.70	-	-	-	
Township 11, Pleasant Grove	3 200	999	602	623	125	197	182	78	60	2.78	3.14	5	5	-	
Township 12, Burlington	32 000	13 898	9 085	6 536	2 110	4 813	4 288	1 979	1 639	2.33	2.91	471	414	57	
Burlington city (pt.)	28 000	12 373	7 987	5 746	1 877	4 386	3 956	1 821	1 516	2.30	2.90	459	402	57	
Glen Raven CDP (pt.)	4 000	509	383	277	81	126	109	46	39	2.57	3.00	12	12	-	
Township 13, How River	1 000	1 930	1 443	1 052	299	487	422	167	136	2.55	2.95	10	10	-	
Burlington city (pt.)	-	67	40	32	4	22	21	11	7	1.98	2.43	-	-	-	
Graham city (pt.)	-	696	502	382	96	194	179	85	70	2.36	2.82	-	-	-	
Simpsonville CDP (pt.)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Carter County	27 200	10 331	8 049	6 715	952	2 282	2 022	839	651	2.64	3.02	299	299	-	
Middle township	3 000	1 125	897	773	77	228	202	87	58	2.71	3.07	-	-	-	
Haltersville township	1 600	684	543	477	39	141	122	58	43	2.72	3.07	-	-	-	
How River township	4 000	230	187	160	19	43	41	17	15	2.74	3.10	-	-	-	
Hershey township	1 100	422	335	279	45	87	79	29	23	2.75	3.15	-	-	-	
Hershey township	4 000	1 554	1 178	974	148	376	330	169	141	2.62	3.05	-	-	-	
Stony Point CDP (pt.)	1 000	436	331	274	23	105	93	58	49	2.59	3.03	-	-	-	
How River township	1 000	302	266	23	23	98	83	33	25	2.56	2.99	-	-	-	
How River township	6 000	3 136	2 350	1 838	386	786	717	323	255	2.56	3.00	299	299	-	
How River township	1 000	637	397	277	99	240	228	116	96	2.22	2.86	149	149	-	
How River township	7 000	2 780	2 257	1 946	215	523	448	122	91	2.67	2.97	-	-	-	
Bethlehem CDP	3 000	1 166	966	848	85	220	191	47	35	2.67	2.99	-	-	-	
Carter County	3 894	2 894	2 281	2 421	303	1 055	990	433	433	2.41	2.88	209	193	16	
Carter County	1 000	485	371	334	27	115	106	49	34	2.48	2.88	-	-	-	
Carter County	1 000	189	134	113	10	54	44	19	13	2.40	2.79	-	-	-	
Carter County	1 000	1 484	1 016	928	151	468	420	253	214	2.34	2.89	209	193	16	
Carter County	1 000	609	484	365	100	325	307	180	155	2.17	2.88	198	193	5	
Carter County	2 000	868	659	587	54	209	201	118	97	2.46	2.88	-	-	-	
Carter County	1 000	271	207	185	17	64	53	29	24	2.46	2.88	-	-	-	
Carter County	1 000	317	234	197	23	83	73	43	31	2.42	2.85	-	-	-	
Carter County	1 000	208	177	177	21	72	62	28	20	2.47	2.90	-	-	-	
Carter County	20 000	8 531	6 359	4 552	1 475	2 172	2 042	1 075	860	2.71	3.23	357	344	13	
Carter County	1 000	573	454	333	92	119	110	55	48	2.76	3.16	-	-	-	
Carter County	1 000	202	165	106	47	38	36	20	16	3.02	3.45	-	-	-	
Carter County	1 000	530	421	358	44	109	104	63	47	2.55	3.04	-	-	-	
Carter County	2 000	725	570	470	113	155	144	66	50	2.89	3.33	-	-	-	
Carter County	2 000	1 047	817	652	126	235	224	126	97	2.77	3.24	129	120	-	
Carter County	1 000	135	107	81	23	28	28	17	15	2.64	3.33	-	-	-	
Carter County	1 000	236	148	110	46	68	54	40	28	2.81	3.42	-	-	-	
Carter County	3 000	1 267	961	686	224	301	284	151	124	2.76	3.26	-	-	-	
Carter County	1 000	165	125	96	21	60	60	33	36	2.53	3.18	-	-	-	
Carter County	1 000	625	437	274	138	188	175	93	79	2.78	3.45	-	-	-	
Carter County	1 000	38	26	19	7	12	11	7	6	2.58	3.27	-	-	-	
Carter County	1 000	221	154	84	64	67	62	35	30	2.67	3.27	-	-	-	
Carter County	1 000	623	2 597	1 744	719	1 036	948	505	408	2.62	3.20	237	224	13	
Carter County	3 000	1 407	943	597	300	444	438	235	197	2.50	3.15	152	119	13	
Carter County	1 000	136	107	83	17	29	29	16	7	2.85	3.32	-	-	-	
Carter County	21 000	8 848	6 748	5 643	816	2 100	1 935	1 014	809	2.48	2.89	244	220	24	
Carter County	1 000	203	155	132	15	48	45	27	22	2.64	3.07	-	-	-	
Carter County	1 000	672	524	460	46	148	135	82	62	2.52	2.70	-	-	-	
Carter County	1 000	17	15	15	2	2	2	2	1	2.71	2.93	-	-	-	
Carter County	1 000	210	162	146	10	48	41	24	23	2.47	2.84	7	7	-	
Carter County	1 000	159	113	94	12	46	43	17	12	2.43	2.94	-	-	-	
Carter County	1 000	301	239	207	23	62	61	35	26	2.56	2.95	-	-	-	
Carter County	1 000	241	198	168	23	43	42	26	19	2.65	2.98	-	-	-	
Carter County	1 000	216	168	140	20	48	45	20	13	2.64	3.06	-	-	-	
Carter County	3 000	1 440	1 062	855	168	378	343	173	153	2.41	2.84	229	220	-	
Carter County	1 000	474	329	256	65	145	135	72	63	2.78	2.78	220	220	-	
Carter County	1 000	179	149	125	16	30	28	17	1						

(URL reload)

1990 US Census Data
Database: C90STF1A
Summary Level: State--County

Anson County: FIPS.STATE=37, FIPS.COUNTY90=007

PERSONS

Universe: Persons

Total.....23474

PERSONS PER OCCUPIED HOUSING UNIT

Universe: Occupied housing units

Persons per occupied housing unit.....2.71

North Carolina Administrative Code

Title 15A

**Department of Environment, Health, and Natural Resources
Division of Environmental Management**



Subchapter 2L

**Sections .0100,
.0200, and .0300**

**Classifications and
Water Quality
Standards
Applicable To The
Groundwaters of
North Carolina**

**Current Through November 8, 1993
Environmental Management Commission
Raleigh, North Carolina**

- (42) heptachlor: 8.0×10^{-6}
- (43) heptachlor epoxide: 4.0×10^{-6}
- (44) heptane: 2.1
- (45) hexachlorobenzene (perchlorobenzene): 0.00002
- (46) n-hexane: 0.42
- (47) iron: 0.3
- (48) lead: 0.015
- (49) lindane: 2.0×10^{-4}
- (50) manganese: 0.05
- (51) mercury: 0.0011
- (52) metadichlorobenzene (1,3-dichlorobenzene): 0.62
- (53) methoxychlor: 0.035
- (54) methylene chloride (dichloromethane): 0.005
- (55) methyl ethyl ketone (MEK; 2-butanone): 0.17
- (56) methyl tert-butyl ether (MTBE): 0.2
- (57) nickel: 0.1
- (58) nitrate: (as N) 10.0
- (59) nitrite: (as N) 1.0
- (60) orthodichlorobenzene (1,2-dichlorobenzene): 0.62
- (61) oxamyl: 0.175
- (62) paradichlorobenzene (1,4-dichlorobenzene): 0.075
- (63) pentachlorophenol: 0.0003
- (64) pH: 6.5 - 8.5
- (65) radium-226 and radium-228 (combined): 5 pCi/l
- (66) selenium: 0.05
- (67) silver: 0.018
- (68) styrene (ethenylbenzene): 0.1
- (69) sulfate: 250.0
- (70) tetrachloroethylene (perchloroethylene; PCE): 0.0007
- (71) toluene (methylbenzene): 1.0
- (72) toxaphene: 3.1×10^{-5}
- (73) 2, 4, 5,-TP (Silvex): 0.05
- (74) trans-1,2-dichloroethene: 0.07
- (75) 1,1,1-trichloroethane (methyl chloroform): 0.2
- (76) trichloroethylene (TCE): 0.0028
- (77) trichlorofluoromethane: 2.1
- (78) vinyl chloride (chloroethylene): 1.5×10^{-5}
- (79) xylenes (o-, m-, and p-): 0.53
- (80) zinc: 2.1

(h) Class GSA Standards. The standards for this class shall be the same as those for Class GA except as follows:

- (1) chloride: allowable increase not to exceed 100 percent of the natural quality concentration.
- (2) total dissolved solids: 1000 mg/l.

(i) Class GC Waters.

- (1) The concentrations of substances which, at the time of classification exceed the standards applicable to Class GA or GSA groundwaters shall not be caused to increase, nor shall the concentrations of other substances be caused to exceed the

NATIONAL FLOOD INSURANCE PROGRAM

FIRM
FLOOD INSURANCE RATE MAP

TOWN OF
WADESBORO,
NORTH CAROLINA
ANSON COUNTY

(ONLY PANEL PRINTED)

COMMUNITY-PANEL NUMBER
370006 0005 B

EFFECTIVE DATE:
AUGUST 19, 1986



Federal Emergency Management Agency

Certain areas not in the special flood hazard areas (zones A and V) may be protected by flood control structures.

This map is for flood insurance purposes only; it does not necessarily show all areas subject to flooding in the community or all planimetric features outside special flood hazard areas.

INITIAL IDENTIFICATION:

DECEMBER 28, 1973

FLOOD HAZARD BOUNDARY MAP REVISIONS:

JULY 2, 1976

FLOOD INSURANCE RATE MAP EFFECTIVE:

AUGUST 19, 1986

FLOOD INSURANCE RATE MAP REVISIONS:

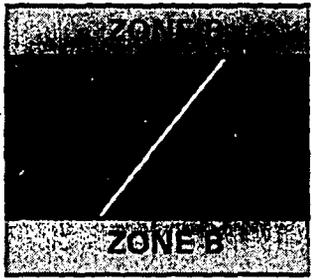
To determine if flood insurance is available in this community, contact your insurance agent, or call the National Flood Insurance Program, at (800) 638-6620.



APPROXIMATE SCALE

1000 0 1000 FEET

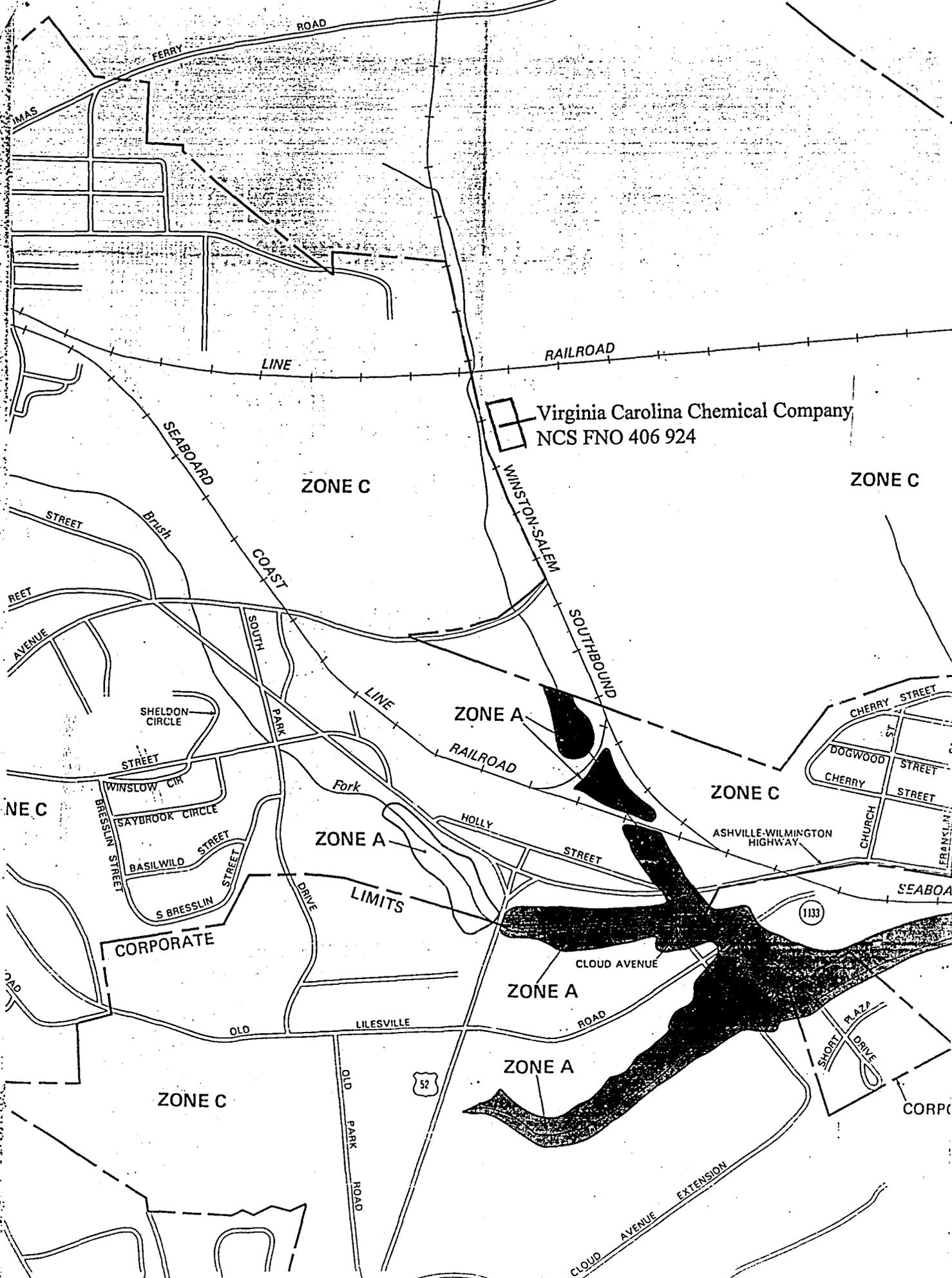
KEY TO MAP

500-Year Flood Boundary	—————	
100-Year Flood Boundary	—————	
Zone Designations*		
100-Year Flood Boundary	—————	
500-Year Flood Boundary	—————	
Base Flood Elevation Line With Elevation In Feet**	~~~~~513~~~~~	
Base Flood Elevation in Feet Where Uniform Within Zone**		(EL 987)
Elevation Reference Mark		RM7 _X
Zone D Boundary	—————	
River Mile		•M1.5

**Referenced to the National Geodetic Vertical Datum of 1929

*EXPLANATION OF ZONE DESIGNATIONS

ZONE	EXPLANATION
A	Areas of 100-year flood; base flood elevations and flood hazard factors not determined.
A0	Areas of 100-year shallow flooding where depths are between one (1) and three (3) feet; average depths of inundation are shown, but no flood hazard factors are determined.
AH	Areas of 100-year shallow flooding where depths are between one (1) and three (3) feet; base flood elevations are shown, but no flood hazard factors are determined.
A1-A30	Areas of 100-year flood; base flood elevations and flood hazard factors determined.
A99	Areas of 100-year flood to be protected by flood protection system under construction; base flood elevations and flood hazard factors not determined.
B	Areas between limits of the 100-year flood and 500-year flood; or certain areas subject to 100-year flooding with average depths less than one (1) foot or where the contributing drainage area is less than one square mile; or areas protected by levees from the base flood. (Medium shading)
C	Areas of minimal flooding. (No shading)
D	Areas of undetermined, but possible, flood hazards.
V	Areas of 100-year coastal flood with velocity (wave action); base flood elevations and flood hazard factors not determined.
V1-V30	Areas of 100-year coastal flood with velocity (wave action); base flood elevations and flood hazard factors determined.



Virginia Carolina Chemical Company
NCS FNO 406 924

ZONE C

ZONE C

ZONE A

ZONE C

ZONE A

ZONE A

ZONE A

ZONE C

CORP

Memorandum

DATE: May 14, 1999

TO: File

FROM: Scott C. Ryals 
Environmental Chemist
NC Superfund Section

SUBJECT: Natural Heritage Program Trip Report

Virginia Chemical Company
Wadesboro, Anson County, NC
EPA ID: NCD TBA

On Monday, May 10, 1999, Scott Ryals and Dan LaMontagne of the NC Superfund Section reviewed the topographic maps located at the NC Heritage Program in the Archdale Building in downtown Raleigh, NC. The purpose of the trip was to identify and record the locations of the endangered or threatened species, special concern species, priority areas and sensitive environments within the 4.0 mile radius of the subject site and along the 15 mile downstream surface water pathway.

The alphanumeric designations (i.e. B4) refer to the colored circles on the map and indicate the location of each of the endangered or threatened species, special concern species, priority areas and sensitive environments within the 4.0 mile radius of the subject site and along the 15 mile downstream surface water pathway.

A plant species, *Sedum pusillum*, B1,2,3,5, (Puck's Orpine), classified as NC-E, S1 (Endangered in NC, Critical Imperiled) was identified at several locations within the 4.0 mile radius of the subject site--approximately 2.5, 3.5 and 4.0 miles.

A plant species, *Minuartia uniflora*, B4, (Single-Flowered Sandwort), classified as NC-E, S1 was identified immediately outside of the 4.0 mile radius. The location of the habitat of this plant (margins of a surface water body), although outside of the 4.0 mile radius, was bisected by the 4.0 mile radius and therefore could be potentially impacted.

A Registered Natural Heritage Area, R1, (Millseat Outcrop) was identified to be located approximately 2.75 miles from the site.

A prominent geological feature, Br1 (GFR-Fyb.001) and a sensitive environment, G1&2, (Granite Flatrock) were identified to be located approximately 4 miles from the site with G1 being approximately 2.5 miles from the site.

A NC Priority Area, O1, (Martins Rock) was identified to be located approximately 4.0 miles from the site.

No additional endangered or threatened species, special concern species and sensitive environments were found to be located within the 4.0 mile radius of the site or along the 15 mile surface water pathway.

- B1 Moose Lake *Sedum pusillum* 002
- B2 *Sedum pusillum* 004

- f1 granite Flatrock 003
- f2 granite Flatrock 007
- R1 RHA Millarat Outcrop (Legislated Natural Heritage Area)

- B3 *Sedum pusillum* 003
- B4 *Mimuartia uniflora* 005
- B5 *Sedum pusillum* 001

01 Priority Area: Martins Look

Br1 Geologic Feature: GFR-Fyp.001

Sedum pusillum, Peck's Orpine
 NC-E, SI critical imperiled

Rare Plant

Mimuartia uniflora, Single-flowered
 Sandwort"
 NC-E, SI critical imperiled

SITE DISCOVERY FORM

Part I: Information necessary to add a site to CERCLIS

ACTION: A

EPA ID:

SITE NAME: VC Chemical -- Wadesboro

SOURCE: T (R=EPA, T=STATE)

STREET: Stanback Ferry Road

CONG DIST: 8

CITY: Wadesboro

ZIP: 28170

CNTY NAME: Anson Co.

CNTY CODE: 4

LATITUDE: 34° /58' /22"

LONGITUDE: 80° /03' /26"

INVENTORY IND: Y REMEDIAL IND: Y REMOVAL IND: N FED FAC IND: N

RPM NAME:

RPM PHONE: - - (EPA Project Officer)

SITE DESCRIPTION: The 10.38-acre site operated as a fertilizer facility from approximately 1908 to 1945. A 1930 Sanborn map of this site shows that lead chambers were used to manufacture sulfuric acid. The current owner, Mr. Carl Weston, purchased the property from Anson County in the early 1980s. The site is about ½ mile from the town limits of Wadesboro, population 3,820. The nearest water lines are located ½ mile from the site.

The property is vacant, unused, and unfenced with no signs of recreation. There is uninhabitable house trailer on the property and an old well. Near the well is a 100,000-gallon fire protection reservoir containing water. Some of the railroad beds contain a white, granular substance. Several small brick buildings and the support structure for the old lead chambers remain on the site. There is magenta-colored soil, characteristic of lead contamination, in the vicinity of and downgradient from the chamber area. This discolored soil is on the site property but within 200' of a drinking water well serving an uninhabited residential property.

There are three residences served by drinking water wells on property adjacent to the facility. Another three residences and a small business, all served by drinking water wells, lie downgradient from and in close proximity to the overland pathway leading from the site. All residences within ½ mile appear to be served by drinking water wells.

There are two probable points of entry (PPE) to surface water at two points in an unnamed tributary to Brush Fork. The northern PPE is about 100' west of the site. The southern PPE that receives runoff from the magenta-colored soil area is about 750' south of the site. The wetland inventory map shows the nearest wetland about 1 ½ miles downstream of the PPE; however, vegetation observed during the site visit and the topography of the area adjacent to the stream bed approximately 100' below the southern PPE indicates the potential for a wetland area much closer to the site.

Part 2: Other site information

DATE SITE FIRST

REPORTED: / /

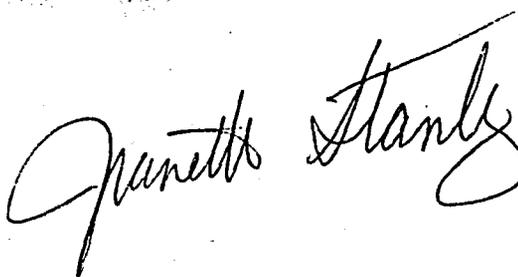
REPORTED BY: State (NC Superfund Section)

REASON FOR LISTING:

Based on the potential for this site has a potential to release lead and other contaminants to six residential drinking water wells and wetlands.

MEMO

DATE: January 13, 1999
TO: File
FROM: Jeanette Stanley
Environmental Chemist
NC Superfund Section
RE: VC Chemical -- Wadesboro
Wadesboro, Anson Co., NC



On December 17, 1998, Serafino Franch, Environmental Chemist, and I visited the VC Chemical Wadesboro site. This site was originally recommended for investigation by Irene Williams, NC Superfund Section. We obtained a key to the gate from Al Scarborough at Scarborough Hardware. The property was posted and inaccessible by vehicle. Mr. Scarborough said he owned adjacent property and had found it necessary to restrict access due to trash dumping and wild parties. Mr. Scarborough said that the current property owner, Mr. Weston, had lived in the on-site house trailer at one time.

As we entered the property, we walked near the former lead acid chamber area (as indicated on the Sanborn maps) and noted the characteristic magenta-colored soil (indicating lead contamination) in the vicinity. We noticed that there were nearby residents and that one resident was in her yard. We walked to her yard and introduced ourselves. She gave us her name and address:

Mrs. William T. Wall
Rt. 2 Box 9
Wadesboro, NC 28170 (704) 694-3560

Mrs. Wall said that her husband was recovering from a recent stroke. She said that her neighbor, Reverend Leon Tyson was also recovering from a stroke. The other house close to the site was vacant at the time of our site visit, but Mrs. Wall said she anticipated that someone would be moving into the home. I called today and she said that the home was now rented and it appeared as if the residents were still moving. She did not know if the new residents have children. All three homes use groundwater wells for drinking. Mrs. Wall said that another neighbor closer to Stanback Ferry Road was named Robert "Patchie" Clark. She said that the three homes that were occupied during our site visit housed two residents each, all elderly couples. Mrs. Wall said that she did not know of anyone who ever entered the former fertilizer property. She had never been on the adjacent property. We noted a vegetable garden between the Wall home and the nearby vacant home. We then began our tour of the site, taking a number of photographs:

- Photo #1 Looking north toward former acid chambers
- Photo #2 Characteristic magenta-colored soil and sulfur. Area within 200' of garden and closest drinking water well.
- Photo #3 Outfall of old terra cotta pipe, vacant residence in background
- Photo #4 Note well house to left of house.
- Photo #5 Acid Chamber area, looking west from yard of vacant home. Note corner of concrete wall.

MEMO TO: File
DATE: January 13, 1998
page 2

Photo #6 Small Brick buildings to the South of the former acid chambers building
Photo #7 Small Brick buildings to the South of the former acid chambers building
Photo #8 Small Brick buildings to the South of the former acid chambers building

We then walked up the berm on the east side of the facility and found that the facility included a concrete wall that had been constructed to support a two-story- high bank of dirt which supported a former railroad track. Photo #9 was taken looking west from the top of the berm toward the edge of wall. We then walked down the northern end of the berm and toward center of the property. We noted a vacant, uninhabitable house trailer, Photo #10. We then walked to the front of the trailer and photographed the old reservoir and water tank in background (Photos #11 & 12). A well was noted about 15' northwest of the reservoir. The well had a short concrete culvert as housing with no top. (During a telephone conversation, Mr. Weston said that he had used this well for drinking when he lived on the property.) There was no visible tap or labeling on the well. Proceeding northward along the western perimeter of the former facility, we noted a white, granular substance that looked like old fertilizer (Photos #13 & #1 (roll 2)) filling the former railroad bed.

The area was very thick with briars and undergrowth. We found an opening and, in a northeasterly direction, crossed over the concrete pad of the former dump shed and fertilizer mixing building. Small trees and other vegetation were growing in the cracks of the pad throughout. There was standing water in some areas of the pad. There were signs of past "recreational use" of the property such as beer cans, but no signs of recent use.

Photo #2 (roll 2) was taken from the rear of the former building, standing in the former road bed and looking south toward the degraded pad. Photo #3 (roll 2) was taken of the ditch draining the rear (north) of the building. Photos #4, #5 & #6 (roll 2) were taken of the former railroad bed and loading platform at the northwest corner of the facility. Proceeding along the western perimeter of the property, we attempted to locate a surface water outfall. Serafino located a culvert under the former railroad bed and the outfall into the unnamed tributary (UT) to Brush Fork. Photos #7 & #8 (roll 2) were taken of the stream the receives the overland flow from the northern half of the property.

We had then essentially circled the property. We located the magenta-colored soil again (Photo #9 (roll 2)), and then followed the overland pathway from this area of soil. We noted a large dog running loose and decided to return to the vehicle and attempt to locate the PPE for the southern half of the property from the vehicle. We determined that there were no additional culverts under the former railroad bed on the north side of Stanback Ferry Road. The overland pathway follows a ditch to the west of the nearby homes and to the east of the former railroad bed and then enters a culvert under the road. On the south side of Stanback Ferry Road, the overland pathway follows a low area along the perimeter of a residential property and then enters a flowing stream at the rear of the home. This stream flows in a westerly direction, through a culvert under the former railroad bed and into the UT to Brush Fork.

MEMO TO: File
DATE: January 13, 1998
page 3

While investigating the overland pathway, we noted a "backyard garage" facility that was operating and an additional home on the north side of Stanback Ferry Road not discussed by Mrs. Wall, making a total of five homes and a garage on the north side of Stanback Ferry Road. The one home on the south side of Stanback Ferry home near the site would makes a total of six homes, three homes within 200' of the facility and another three homes and a garage in close proximity to the overland pathway and downgradient from the site. All homes use wells for drinking.

I called Mrs. Wall today and she said that one of the two homes close to Stanback Ferry Road on the north side is unoccupied. The other home is occupied by Mr. and Mrs. Robert Clark. The brick home on the south side of Stanback Ferry Road is occupied by "Boot" Clark, a relative of Mr. Robert Clark's. Mrs. Wall said that Mr. Robert Clark operates the garage.

Memorandum

DATE: May 20, 1999

TO: File

FROM: Scott C. Ryals
Environmental Chemist
NC Superfund Section

SUBJECT: Community Well Usage Within 4.0 Mile Radius

Virginia Chemical Company
Wadesboro, Anson County, NC
EPA ID: NCD TBA

The Public Water Supply Database was queried for community wells within the 4.0 mile radius for the site. No community wells were identified within the target distance. A surface water intake for the City of Wadesboro, Anson County, North Carolina serving 6510 people was identified within the 4.0 mile radius (See site topographical map, figure 1).

Virginia Chemical Company
Wadesboro, Anson County, North Carolina

NCD # TBA
Public Water Supply Database
May 20, 1999

<u>PWS I.D.</u>	<u>System Name</u>	<u>Type</u>	<u>Pop.</u>	<u>Phone No.</u>	<u>Source Name</u>	<u>Source</u>		<u>Latitude</u>	<u>Longitude</u>
						<u>Type</u>	<u>Avail</u>		
0304020	Town of Wadesboro	C	6510	704-694-5171	City Lake	S	P	345523	800451
0304432	Olivet United Methodist Ch.	N	25	704-848-4694	Well # 1	G	P	350130	795930

PWS I.D. = Public Water Supply System Identification Number

Type: C = Community, P = Private, N = Non-Community

Pop. = Population served by Water System

Source Type: S = Surface Water Intake, G = Groundwater

Source Avail: P = Permanent

Site Name: V.C. Chemical - Wadesboro
 Site Number: NCD TBA
 Site Location: Wadesboro, Anson County, N.C.
 Latitude: 34 57 30.0
 Longitude: 080 02 30.0
 Date: May 20, 1999

Calculation Results

Distance from Site Location	Population		Number of Households	
	Per Ring	Cumulative	Per Ring	Cumulative
0 to 1/4 mile	142	142	55	55
>1/4 to 1/2 mile	163	305	57	112
>1/2 to 1 mile	856	1,161	317	429
>1 to 2 miles	2,571	3,732	1,048	1,477
>2 to 3 miles	4,623	8,355	1,822	3,299
>3 to 4 miles	2,262	10,617	846	4,145

Note: The populations and number of households within specified target distance rings were calculated for the NC Superfund Section by the NC Center for Geographic Information and Analysis using the 1990 US Census data. These values were calculated by summing the population and the number of households data for each census block located within each target ring. For census blocks lying only partially within the ring, the per cent area of the block within the ring was multiplied by the population and household densities of the block.

Memorandum

December 21, 1999

To: File

From: Scott Ryals
Environmental Chemist
NC Superfund SectionSubject: Wetlands Along 15-Mile Pathway
VCC-Wadesboro
Wadesboro, Anson County, NC
EPA ID: NCSFN 0406 924

Using an American Map Corp. Map Measurer and the 1:24000 scale USGS topographic map for the Wadesboro region, the 15-mile pathway was identified from the VCC-Wadesboro site to a point approximately 0.5 mile east of where Jones Creek passes underneath NC Hwy. 145. The pathway follows an unnamed tributary of Brush Fork Creek for approximately 0.4 miles before it merges with Brush Fork Creek. The pathway follows Brush Fork Creek for approximately 2.3 miles until it merges with Bailey Creek. Bailey Creek flows for approximately 1.9 miles before merging with Jones Creek where the pathway terminates. The first Hazard Ranking System (HRS) identifiable wetland (palustrine forested (PFO)) occurs 1.14 miles downstream of the site within Brush Fork Creek. There are 4.5 miles of PFO wetland frontage along the surface water pathway within four miles of the site. Additional wetland frontage was not determined due to the analytical results of the July 26, 1999 NC Superfund Section PA/SI sampling which indicated that there was not an observed release of the contaminants from the site to the surface water pathway.

Memorandum

Date: December 29, 1999

To: File

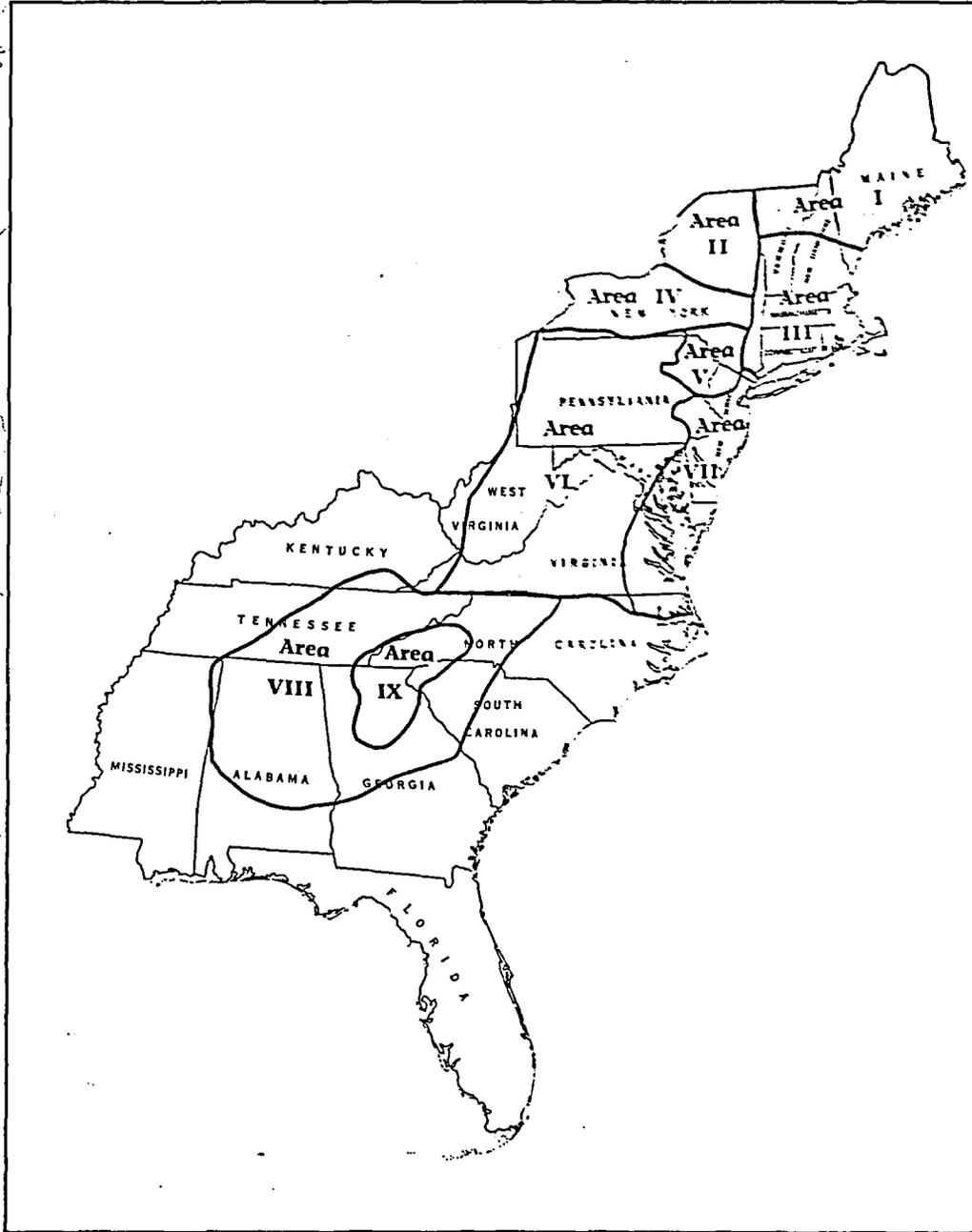
From: Scott Ryals 
Environmental Chemist
NC Superfund Section

Subject: Flow Rate in Brush Fork Creek
VCC-Wadesboro
Wadesboro, Anson County, NC
US EPA ID: NCSFN 0406 924

On Wednesday, December 29, 1999, Scott Ryals and Harry Zinn of the NC Superfund Section calculated the average runoff of the drainage basin for Brush Fork Creek. Using the Wadesboro, USGS topographic map and a Planix Digital Planimeter, the area of the drainage basin was determined to be 388 acres or 0.606 square miles (See attached worksheet). Based on the equation described in the US Geological Survey, Water-Resources Investigations Report 88-4094, the runoff coefficient for the Wadesboro area is 14 inches¹ and the mean annual discharge to the Brush Fork Creek is calculated to be approximately 0.625 cubic feet per second (cfs).

¹ US Geological Survey, Water-Resources Investigations Report 88-4094. Map of the Mean Annual Runoff for the Northeastern, Southeastern and Mid-Atlantic United States, Water Years 1951-80.

MAP OF MEAN ANNUAL RUNOFF FOR THE NORTHEASTERN, SOUTHEASTERN, AND MID-ATLANTIC UNITED STATES, WATER YEARS 1951-80



Prepared in cooperation with the
U.S. Environmental Protection Agency



sions that the methods that used the area-weighted average of the drainage area or the centroid of the drainage area produced somewhat better correlations—that is, the intercept was closer to zero, the standard errors were small, and the correlation coefficients were larger. These methods have slightly greater power to predict actual runoff.

Additional statistical investigation found no significant differences in reliability of the runoff estimates among the areas. No significant differences existed in the errors for stations with drainage areas of differing size.

USE OF MEAN ANNUAL RUNOFF MAP

Mean annual runoff for a site can be estimated from the runoff map by several methods. The simplest method of estimating the runoff is to locate the site on the runoff map and to identify the runoff contour nearest the site. This method, however, is less accurate than other methods. The most accurate method is to draw the drainage basin on the runoff map, and use the runoff contours to divide the basin into bands of differing runoff. The area of each of the bands within the drainage basin is then determined. The areas of the separate bands are then used to compute a weighted average runoff for the basin. For example, if 50 percent of the basin is in an area of 18 in/yr (inches per year) of runoff, 30 percent in an area of 20 in/yr of runoff and 20 percent in an area of 22 in/yr of runoff the mean annual runoff would be calculated as follows:

$$0.5 \times 18 + 0.3 \times 20 + 0.2 \times 22 = 19.4$$

Runoff estimated from the map is in inches per year, averaged over the entire drainage basin. Multiply this value by the drainage area, in square miles, and divide by 13.58 to convert to mean annual discharge, in cubic feet per second. In the above example, assume the drainage area of the site is 100 mi². The mean annual discharge, in cubic feet per second, would be:

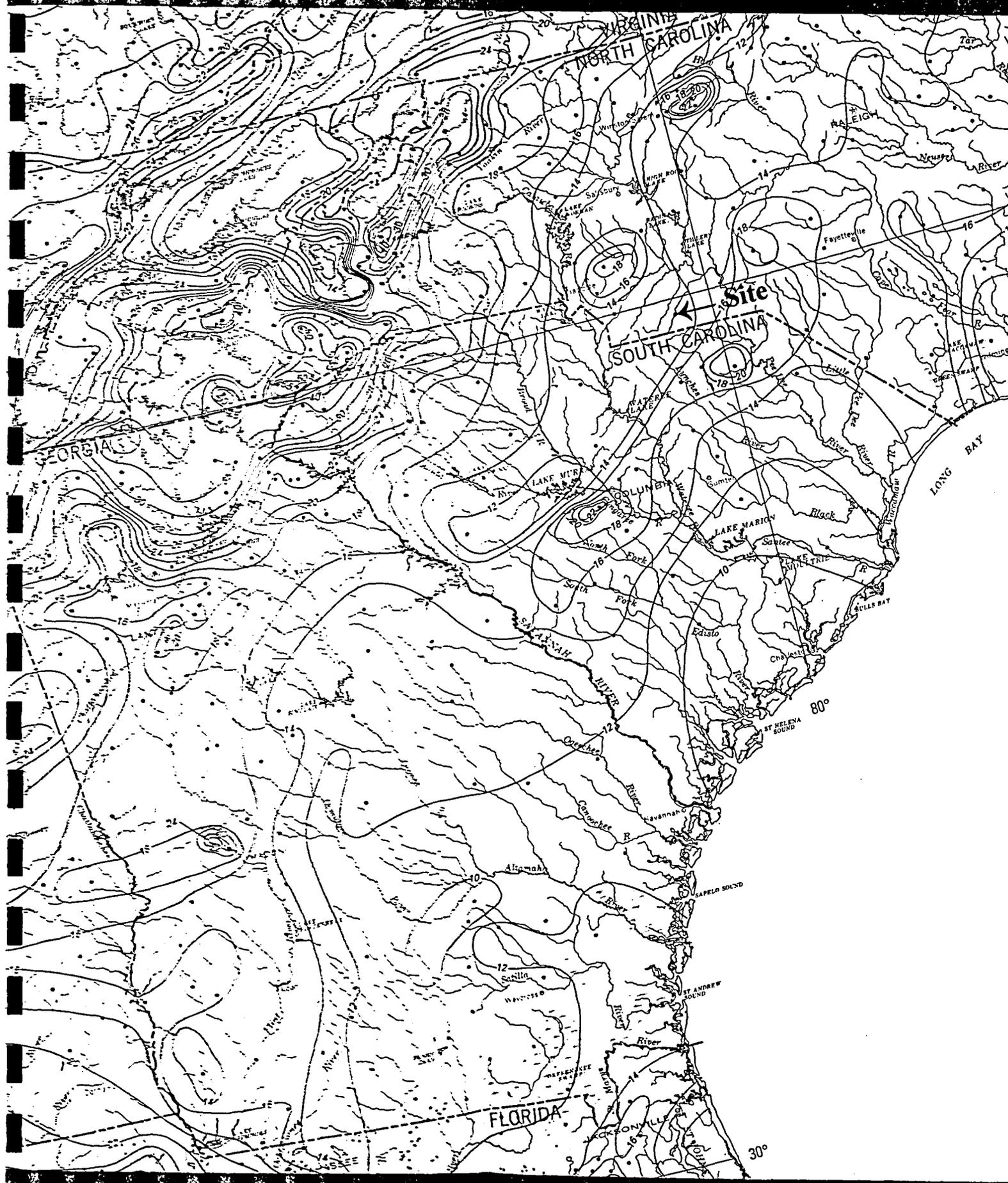
$$19.4 \times 100 / 13.58 = 143$$

The runoff map was prepared to allow estimation of mean annual runoff at sites where no streamflow data are available. The map represents mean annual runoff for areas with natural land cover. Caution should be used in applying the map to estimate runoff for areas that are not natural land areas. The runoff map should not be used for areas, such as large urban areas, where the land cover has been altered in ways that would change the amount of runoff. The runoff map is not applicable for lakes or bays, for coastal wetlands affected by tides, for streams controlled by reservoirs large enough to influence the total annual streamflow, or for streams with substantial diversions.

Local features could cause the runoff at a particular site to differ substantially from the runoff indicated by the runoff map. The geology of the drainage basin might cause substantial amounts of water to enter or leave the basin as ground water. This could substantially increase or decrease the runoff. For example, a stream with a small drainage area that includes a large spring probably would have higher average streamflow than indicated by the runoff map.

Table 5.—Descriptive statistics of errors in estimated runoff at 93 test stations

Method	Mean absolute value	Mean	Standard error of mean	Standard deviation
<u>Error, in inches</u>				
Area-weighted	2.0	-0.35	0.30	2.9
Centroid	2.2	-.71	.33	3.1
GIS	2.7	-1.74	.37	3.6
Nearest-inch	2.8	-1.77	.38	3.7
Nearest contour	2.8	-1.79	.39	3.8
<u>Percent error</u>				
Area-weighted	9.0	-0.54	1.3	12.9
Centroid	9.8	-.71	1.4	13.5
GIS	12.0	-6.42	1.6	15.9
Nearest-inch	12.1	-6.20	1.6	15.6
Nearest-contour	12.2	-6.26	1.6	15.8



Brush Fork Crk Anson County, NC

AREA: 388 acres

43,560 sq. ft./acre

$$\frac{43,560 \text{ sq. ft.}}{\text{acre}} \bigg| \frac{388 \text{ acres}}{\text{mile}^2} \bigg| \frac{\text{mile}^2}{5280^2 \text{ sq. ft.}}$$

.606 sq. mi.

Runoff: 14 inches

$$\frac{(.606)(14)}{13.58 \text{ (conversion factor)}}$$

0.625 cfs

NORTH CAROLINA'S

1998 303(d) LIST

**Department of Environment and Natural Resources
Division of Water Quality**

May 15, 1998

White Oak River Basin

- The Newport River was originally listed as impaired due to violations of DO and pH standards. However, the Newport River is a swampy, slow moving river that would naturally be expected to have low DO and pH values. North Carolina's regulations allow for water quality below the standards if it is due to natural conditions (15A NCAC 2B .0205). This river should never have been placed on the 303(d) list and was removed for 1998.
- Southwest Creek was not included on the 1996 303(d) list. It was added to the 1998 list based on updated use support information.
- Fifteen acres of estuarine waters located near Sneads Ferry and the Newport River were removed from the 303(d) list for copper since current use support information does not show impairment from copper. Other acres were modified in the estuarine areas based on shellfish closure data and the area impacted by nutrients.

Yadkin-Pee Dee River Basin

- Several waters were included on the 1996 303(d) list that have been removed from the 1998 303(d) list since updated use support information indicates that the water is meeting its uses. These waters include: South UT, Ararat River, Toms Creek, Danbury Creek, Carter Creek, Barkers Creek, Little Creek, Abbotts Creek, Back Creek, Long Creek, one segment of Long Branch, one segment of Richardson Creek, and two segments of Marks Creek.
- The listing for Rich Fork Creek has been combined into one long segment.
- Several waters were not included on the 1996 303(d) list that have been included on the 1998 list based on updated use support information. These waters are: Reynolds Creek, Salem Creek, Fourth Creek, Grants Creek, Brushy Fork, Lick Creek, Pee Dee River, Little Mountain Creek, Rocky River, Coddle Creek, Goose Creek, Crooked Creek, North Fork Crooked Creek, South Fork Crooked Creek, Lanes Creek, Brown Creek, Cartledge Creek, Hitchcock Creek, North Fork Jones Creek, and South Fork Jones Creek.
- Long Lake, Hamlet City Lake, and Rockingham City Lake have been added to the list based on updated use support information. Long Lake was rated as impaired because it has been drained; however, there is a plan in place to restore the lake. Hamlet City Lake is rated as partially supporting its uses, but a local plan has been developed to restore the lake. Hamlet City Lake is also currently drained under an Army Corps of Engineers project to repair the dam. . Since Long Lake and Hamlet City Lake have been drained, a priority of N/A has been assigned to them.
- Ledbetter Lake was added to the 303(d) list based on a fish consumption advisory for mercury. Ledbetter Lake is privately owned and DWQ has no further physical, biological, or chemical information on the lake.



Surface Freshwater Classifications Used in North Carolina

WHAT ARE SURFACE WATER CLASSIFICATIONS?

Surface Water Classifications are designations applied to surface water bodies, such as streams, rivers and lakes, which define the best uses to be protected within these waters (for example swimming, fishing, drinking water supply) and carry with them an associated set of water quality standards to protect those uses. Surface water classifications are one tool that state and federal agencies use to manage and protect all streams, rivers, lakes, and other surface waters in North Carolina. Classifications and their associated protection rules may be designed to protect water quality, fish and wildlife, the free flowing nature of a stream or river, or other special characteristics.

HOW DO THEY AFFECT ME?

Before you buy property, plan a new development project, construct a new road or undertake other land use activities, you should check with local, state and federal agencies about the assigned surface water classification for the waterbody on your property. Many of the newer classifications, especially those designed to protect drinking water supplies and certain high quality waters, have protection rules which regulate some land or disturbance other human activities.

WHY DO THEY SOMETIMES OVERLAP?

Many streams, rivers and lakes may have several classifications applied to the same area. This is because surface waters are classified to protect different uses or special characteristics of the waterbody. For example, a stream or specific stream segment may be classified as Class WS-III Tr HQW by the NC Division of Water Quality (DWQ). This protects it as a drinking water supply (WS-III), as Trout Waters (Tr) and as High Quality Waters (HQW). The stream segments upstream or downstream may have different classifications based on other water uses or stream characteristics.

STREAM'S CLASSIFICATION?

DWQ classifies all surface waters. A waterbody's classification may change at the request of a local government or citizen. DWQ reviews each request for a reclassification and conducts an assessment of the waterbody to determine the appropriateness of the reclassification. DWQ also conducts periodic waterbody assessments which may result in a recommendation to reclassify the waterbody. In order for a waterbody to be reclassified it must proceed through the rule-making process.

If you would like to obtain a Schedule of Classifications for a river basin, or a complete set of schedules (17 schedules), or if you need assistance in determining the classification of a waterbody, contact the DWQ central office in Raleigh, (919) 733-5083, or any of the regional offices. You should also contact other agencies listed in this brochure for any of their classifications which may apply.

Central Office
Aldridge Renn
Water Quality Section
Planning Branch
P.O. Box 29535
Raleigh, NC 27626-0535
(919) 733-5083, x 564
FAX (919) 715-5637

Asheville Regional Office
Roy Davis/Reg. Supervisor
Forrest Westall/WQ Supervisor
Interchange Building
59 Woodfin Place
Asheville, NC 28801
(704) 251-6208
FAX (704) 251-6098

Fayetteville Regional
Tommy Stevens/Reg. S
Mike Wicker/WQ Super
Wachovia Building
Suite 714
Fayetteville, NC 283
(910) 486-1541
FAX (910) 486-0707

Mooresville Regional Office
Keith Overcash/Reg. Supervisor
Rex Gleason/WQ Supervisor
919 North Main Street
Mooresville, NC 28115

Washington Regional Office
Jim Mulligan/Reg. Supervisor
Roger Thorpe/WQ Supervisor
1424 Carolina Avenue
Washington, NC 27889

Wilmington Regional
Rick Shiver/Reg. Sup
Dave Adkins/WQ Super
127 Cardinal Drive E
Wilmington, NC 28405

(704) 663-1699
FAX (704) 663-6040

(919) 946-6481
FAX (919) 975-3716

(910) 395-3900
FAX (919) 350-2004

Winston-Salem Regional Office
Larry Coble/Reg. Supervisor
Steve Mauney/WQ Supervisor
585 Waughtown Street
Winston-Salem, NC 27107
(910) 771-4600
FAX (910) 771-4631

Raleigh Regional Office
Ken Schuster/Reg. Supervisor
Judy Garrett/WQ Supervisor
3800 Barrett Drive, P.O. Box 27687
Raleigh, NC 27609
(919) 571-4700
FAX (919) 571-4718

HOW CAN THIS BROCHURE HELP ME?

This brochure provides an overview of the various surface freshwater classifications (excluding Swamp Waters) used in North Carolina and their effect on different land uses or other human activities. It is based on the classifications and their associated rules as of September 1, 1992. Classifications and their rules are regularly updated and revised, so check with the appropriate agencies before starting any project.

The rules presented in this document are based on the minimum protection rules of state and federal agencies. Local governments, in most cases, can adopt more stringent land use or water resource protection rules. Check with the local government(s) that has jurisdiction over your land for any local rules and procedures that may apply.

WHERE CAN I GET MORE INFORMATION?

More detailed information is available in a handbook entitled, *High Quality What? A Guide to Surface Freshwater Classifications in North Carolina* or by reviewing additional information on this website. Written copies of the Schedule of Classifications and surface water quality standards may be obtained from the NC Division of Water Quality, Water Quality Planning Branch, P.O. Box 29535, Raleigh, NC 27626-0535, or by calling (919) 733-5083, extension 564.

DWQ PRIMARY CLASSIFICATIONS

All surface waters in North Carolina are assigned a primary classification by the NC Division of Water Quality (DWQ). All waters must at least meet the standards for Class C (fishable / swimmable) waters. The other primary classifications provide additional levels of protection for primary water contact recreation (Class B) and drinking water (Water Supply Classes I through V).

*Water Supply I (WS-I)

Waters used as sources of water supply for drinking, culinary, or food processing purposes for those users desiring maximum protection for their water supplies. WS-I waters are those within *natural and undeveloped* watersheds in public ownership with no permitted point source (wastewater) discharges.

*Water Supply II (WS-II)

Waters used as sources of water supply for drinking, culinary, or food processing purposes for those users desiring maximum protection for their water supply where a WS-I classification is not feasible. WS-II waters are generally in *predominantly undeveloped* watersheds.

*Water Supply III (WS-III)

Waters used as sources of water supply for drinking, culinary, or food processing purposes for those users where a more protective WS-I or II classification is not feasible. WS-III waters are generally in *low to moderately developed* watersheds.

***Water Supply IV (WS-IV)**

Waters used as sources of water supply for drinking, culinary, or food processing purposes for those users where a WS-I, II or III classification is not feasible. WS-IV waters are generally in *moderately to highly developed* watersheds or Protected Areas.

Water Supply V (WS-V)

Waters protected as water supplies which are generally upstream and draining to Class WS-IV waters or waters used by industry to supply their employees with drinking water or as waters formerly used as water supply. WS-V has no categorical restrictions on watershed development or wastewater discharges like other WS classifications and local governments are *not* required to adopt watershed protection ordinances.

For numerical information regarding water supplies in North Carolina, please go to our [statistics page](#).

Please see the [Water Supply Watershed Protection home page](#) for more information regarding waters classified as water supply.

Class B

Waters used for primary recreation and other uses suitable for Class C. Primary recreational activities include swimming, skin diving, water skiing, and similar uses involving human body contact with water where such activities take place in an organized manner or on a frequent basis. There are no restrictions on watershed development activities. discharges must meet treatment reliability requirements such as backup power supplies and dual train design.

Class C

Waters protected for secondary recreation, fishing, wildlife, fish and aquatic life propagation and survival, agriculture and other uses suitable for Class C. Secondary recreation includes wading, boating, and other uses involving human body contact with water where such activities take place in an infrequent, unorganized, or incidental manner. There are no restrictions on watershed development activities.

* Wastewater discharge and stormwater management requirements are applicable.

DWQ SUPPLEMENTAL CLASSIFICATIONS

Supplemental classifications are sometimes added by DWQ to the primary classifications to provide additional protection to waters with special uses or values.

Future Water Supply (FWS)

Supplemental classification for waters intended as a future drinking water source. FWS would be applied to one of the primary water supply classifications (WS-I, WS-II, WS-III, or WS-IV). State permitting requirements applicable to the primary water supply classification become effective upon reclassification. However, local government water supply protection ordinances are not required until after the FWS supplemental classification is removed.

High Quality Waters (HQW)

Supplemental classification intended to protect waters with quality higher than state water quality standards. In general, there are two means by which a water body may be classified as HQW. They may be by definition or they may qualify for HQW and then be supplementally classified as HQW through the rule-making process. The following are HQW by definition: WS-I, WS-II, SA (shellfishing), ORW,

and waters for which DWQ has received a petition for reclassification to either WS-I or WS-II. The following waters can qualify for the supplemental HQW classification: water rated as Excellent by DWQ, Primary Nursery Areas, Native trout waters and Critical Habitat Waters. There are associated wastewater treatment and stormwater runoff controls enforced by DWQ.

Nutrient Sensitive Waters (NSW)

Supplemental classification intended for waters needing additional nutrient management due to their being subject to excessive growth of microscopic or macroscopic vegetation. In general, management strategies for point and nonpoint source pollution control require no increase in nutrients over background levels.

Outstanding Resource Waters (ORW)

Supplemental classification intended to protect unique and special waters having excellent water quality and being of exceptional state or national ecological or recreational significance. To qualify, waters must be rated Excellent by DWQ *and* have one of the following outstanding resource values:

1. Outstanding fish habitat or fisheries,
2. Unusually high level of waterbased recreation,
3. Some special designation such as NC or National Wild and Scenic Rivers, National Wildlife Refuge, etc.
4. Important component of state or national park or forest,
5. Special ecological or scientific significance (rare or endangered species habitat, research or educational areas).

No new or expanded wastewater discharges are allowed and there are associated watershed stormwater controls enforced by DWQ.

Swamp Waters (Sw)

Supplemental classification intended to recognize those waters that generally have naturally occurring very low velocities, low pH and low dissolved oxygen.

Trout Waters (Tr)

Supplemental classification intended to protect freshwaters for natural trout propagation and survival of stocked trout. Affects wastewater discharges but there are no watershed development restrictions except stream buffer zone requirements of NC Division of Land Resources. DWQ's classification is not the same as the NC Wildlife Resources Commission's *Designated Public Mountain Trout Waters* classification.

OTHER AGENCY CLASSIFICATIONS

Federal Wild and Scenic Rivers

A federal government river designation intended to protect certain free flowing rivers or segments with outstanding scenic, recreational, geologic, fish and wildlife, historic, archaeological or other values. There are three river classifications: Wild, Scenic, and Recreational. The designation restricts or prohibits certain "water resources projects." It places no federal land use or development regulations on private lands. Some controls apply to federal lands and are administered by the federal land management agencies (e.g., US Forest Service, National Park Service).

NC Natural and Scenic Rivers

A state government river designation intended to protect certain free flowing rivers or segments with

outstanding natural, scenic, educational, recreational, geologic, fish and wildlife, historic, scientific and other cultural values. There are three river classifications: Natural, Scenic, and Recreational river areas. The designation places no land use or development regulations on developments on private lands except on the construction of dams and other water resources projects. The program is administered by the NC Division of Parks and Recreation.

Designated Public Mountain Trout Waters

A state fishery management classification administered by the NC Wildlife Resources Commission which provides for public access to streams for fishing on private and public lands. It regulates fishing activities only (seasons, size limits, creel limits, and bait and lure restrictions) and is not the same classification as the DWQ Tr classification-which protects water quality.

Appreciation is given to the Land-of-Sky Regional Council which prepared the original version of this document under a Section 205(j) grant from the US Environmental Protection Agency administered by the NC Department of Environment, Health and Natural Resources -- Division of Environmental Management. Some modifications have been made for this reprinting.



(Last Updated: January 7, 1997) [Webmaster]

YADKIN-PEE DEE RIVER BASIN

STREAM NAME	SUB BASIN	INDEX NUMBER	MAP NUMBER	CLASS
ABBOTTS CR ARM OF HI RO LK	YAD04	12-118.5	D18SW7	WS-V&B
ABBOTTS CREEK	YAD07	12-119-(1)	C18SE5	WS-III
ABBOTTS CREEK	YAD07	12-119-(4.5)	D18NW6	WS-III CA
ABBOTTS CREEK	YAD07	12-119-(6)	D18SW2	C
ADAMS BRANCH	YAD14	13-17-36-2	H16NE8	WS-IV
ADAMS CREEK	YAD12	13-17-11-7	F16NE6	C
ADDIES BRANCH	YAD01	12-11	C12SE5	C TR
AFTON RUN	YAD11	13-17-6-6	F16NW5	C
ALEKS BRANCH	YAD15	13-25-31-4	G19NW3	C
ALLIGATOR BRANCH	YAD14	13-17-32-1	G18NW1	C
ALLISON BRANCH	YAD13	13-17-31-5-5-1	G17NE2	C
ALLS FORK	YAD08	12-133-(1)	E18SE7	WS-IV
ALLS FORK	YAD08	12-133-(2)	E18SE7	WS-IV CA
ANDERSON CREEK	YAD12	13-17-13	F16SE9	C
ANDREWS POND	YAD10	13-22	G18SE3	C
ARARAT RIVER	YAD03	12-72-(1)	A16SE7	WS-IV TR
ARARAT RIVER	YAD03	12-72-(4)	A16SE8	WS-IV
ARARAT RIVER	YAD03	12-72-(4.2)	A16SE8	WS-IV CA
ARARAT RIVER	YAD03	12-72-(4.5)	A16SE8	C
ARARAT RIVER	YAD03	12-72-(18)	B16SE2	WS-IV
ARNETT BRANCH	YAD15	13-25-20-7	F19NW6	C HQW
ARNOLD BRANCH	YAD02	12-84-2-2	C15NE5	WS-III
ASHEWORTH BRANCH	YAD15	13-25-11	E19SE9	C
AUSTIN BRANCH	YAD14	13-17-36-15-1	G17SW9	C
BACK CREEK	YAD06	12-108-20-4-2	D15SW7	C
BACK CREEK	YAD06	12-108-21-1-(0.5)	E15SE3	WS-II
BACK CREEK	YAD06	12-108-21-1-(2)	E16NW6	WS-II CA
BACK CREEK	YAD09	13-2-3-3-(0.3)	D19SE7	WS-II
BACK CREEK	YAD09	13-2-3-3-(0.7)	D19SE7	WS-II CA
BACK CREEK	YAD09	13-2-3-3-(1.5)	E19NW3	C
BACK CREEK	YAD11	13-17-7	F16SW7	C
BACK CREEK LAKE	YAD09	13-2-3-3-(0.7)	E19NW3	WS-II CA
BADIN LAKE	YAD08	12-(124.5)	F18NW3	WS-IV&B CA
BAGGETTS CREEK	YAD16	13-40-3-2	H19SE1	C
BAILEY CAMP CREEK	YAD01	12-5	C12SW3	C TR
BAILEY CREEK	YAD02	12-93-2	D17NW2	C
BAILEY CREEK	YAD17	13-42-1-3	H18NE6	C
BALDWINS POND	YAD16	13-39-12-10.5	H20NW4	C
BALES CREEK #	YAD17	13-47-2-1	H17SE3	C
BARKERS BRANCH	YAD14	13-17-40-10	H17NW6	WS-V
BARKERS CREEK	YAD04	12-94-1	B17SE7	C
BARNES CREEK	YAD09	13-2-18-(0.5)	F19NW2	C ORW
BARNES CREEK	YAD09	13-2-18-(2.5)	F19NW4	WS-IV ORW
BARNES MILL CREEK	YAD15	13-25-15-6	F19NE4	C
BARNETT BRANCH	YAD01	12-18	C12SE9	C TR
BASHAVIA CREEK	YAD02	12-81	C17NE4	C
BASIN CREEK	YAD01	12-46-2-2	B14NW6	C TR ORW
BATTLE BRANCH #	YAD04	12-121	E18NW4	C
BAXTER CREEK	YAD06	12-108-18-4	D16SE1	WS-IV
BEAR BRANCH	YAD06	12-108-16-2-2	C15SW1	WS-III
BEAR CREEK	YAD02	12-63-15	B16SW4	C
BEAR CREEK	YAD06	12-108-18-(1)	D16NW3	C
BEAR CREEK	YAD06	12-108-18-(3)	D16NE7	WS-IV
BEAR DEN BRANCH	YAD01	12-40-2-2-1	B13SE4	WS-II TR
BEARPEN BRANCH	YAD01	12-24-8-1-2	C12NE5	C TR ORW
BEARSKIN CREEK	YAD14	13-17-36-6	G16SE7	C
BEAVER CREEK	YAD01	12-25	C13SE7	C TR

BILL BRANCH	YAD04	12-94-5	C17NW9	C
BILL BRANCH	YAD12	13-17-24-2	G17NW5	C
BISHOP CREEK	YAD15	13-25-20-8-1	F19SW2	C HQW
BLACK BRANCH	YAD16	13-40-1	H19NE9	C
BLACK JACK BRANCH	YAD10	13-20-3	H17NE6	C
BLACK ROCK BRANCH	YAD15	13-25-16	F19NE7	C
BLACK RUN CREEK	YAD12	13-17-11-4	F17NW3	WS-II
BLACKS CREEK	YAD02	12-87-1-1	C17SW5	WS-IV
BLACKWELL BRANCH	YAD14	13-17-40-16	G17SE9	C
BLAKE CREEK #	YAD15	13-25-20-13	F19SW3	C
BLANKET CREEK	YAD02	12-90-(1)	C17SW9	C
BLANKET CREEK	YAD02	12-90-(2)	C17SW6	WS-IV
BLEWETT FALLS LAKE	YAD10	13-(15.5)	G19SW9	WS-V&B
BLOOD CREEK	YAD01	12-30	C13SE3	WS-IV&B TR
BLUE BRANCH	YAD06	12-108-18-2-1	D16NE4	C
BLUE BRANCH	YAD15	13-25-36-6	G19NE4	C
BLUE CREEK	YAD01	12-23-1	D13NW2	C TR
BOLES CREEK	YAD17	13-47-2-1	H17SE3	C
BONES FORK CREEK	YAD16	13-39-5	G20SE7	WS-III
BOONE CAMP BRANCH	YAD01	12-24-4	C12NE2	B TR ORW
BOSS BRANCH	YAD04	12-124-1	E18NW2	C
BOST CREEK	YAD12	13-17-12	F16SE6	C
BOWLIN CREEK	YAD01	12-40-2-2	B13SE4	WS-II TR
BOWMAN MILL CREEK	YAD02	12-68	B16SE7	C
BOWSAW BRANCH	YAD14	13-17-43	G18NW9	C
BOYDS LAKE	YAD16	13-45-(2)	H20NW8	C
BRADY BRANCH	YAD06	12-108-20-4-1	D14SE6	C
BRANDON BRANCH	YAD14	13-17-36-14-1	G17SW2	C
BRENDLE BRANCH	YAD02	12-62-14-1	B15SE5	C
BRIDGERS CREEK	YAD15	13-25-24	F19SE5	C HQW
BRIER CREEK	YAD01	12-47	C15NW7	C
BRIER CREEK	YAD09	13-2-1-1	D18SE7	WS-III
BROOKS BRANCH	YAD01	12-46-2-2-3-2	B14NW8	C TR ORW
BROWN CREEK	YAD10	13-20	H17SE4	C
BRUSH FORK	YAD17	13-42-1-3-1	H18NE2	C
BRUSHY CREEK	YAD06	12-108-16-3	C15SW8	WS-III
BRUSHY FORK	YAD03	12-72-9-7-1	A16SW6	WS-IV
BRUSHY FORK	YAD04	12-94-12-6	C18NW7	C
BRUSHY FORK	YAD07	12-119-5-(1)	C18SW9	WS-III
BRUSHY FORK	YAD07	12-119-5-(7)	D18NW8	WS-III CA
BRUSHY FORK BRANCH	YAD04	12-94-12-6-1-1	C18NW8	C
BRYANT BRANCH	YAD05	12-102-10	C16SE8	C
BUCK BRANCH	YAD06	12-108-9-2	D15NW4	WS-IV
BUCK BRANCH	YAD07	12-119-5-1.5	C18SW9	WS-III
BUCK BRANCH	YAD07	12-119-5-6	D18NW5	WS-III
BUCK BRANCH	YAD14	13-17-36-4-1-(1)	H17NW4	WS-IV
BUCK BRANCH	YAD14	13-17-36-4-1-(2)	H16NE6	WS-IV CA
BUCK BRANCH	YAD14	13-17-36-15-2	H17NE1	C
BUCK CREEK #	YAD02	12-64	C16NW2	C
BUCK SHOALS BRANCH	YAD06	12-108-16-5	C15SE4	WS-III
BUCKWHEAT BRANCH	YAD01	12-40-4-2	B13SE6	WS-II TR
BUD CAGLE BRANCH	YAD15	13-25-20-2	F19NW3	C HQW
BUDDLE BRANCH	YAD04	12-121	E18NW4	C
BUFFALO CREEK	YAD01	12-19	C12NE7	C TR
BUFFALO CREEK	YAD05	12-102-14	D17NW4	C
BUFFALO CREEK	YAD10	13-18-1	G18NE7	C
BUFFALO CREEK	YAD15	13-25-38-(0.3)	G19NE7	C
BUFFALO CREEK	YAD15	13-25-38-(0.7)	G19NW9	WS-IV
BUFFALO CREEK	YAD10	13-32-(1)	G19SW8	WS-IV
BUFFALO CREEK	YAD10	13-32-(2)	G19SW8	WS-IV CA
BUFFALO CREEK	YAD14	13-49-2	H16SE3	C
BUFFALO CREEK, NORTH PR	YAD10	13-18-1-1	G18NW9	C

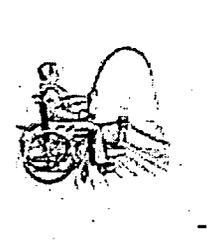
JOHNSON CREEK	YAD03	12-72-3	A16SE4	WS-IV TR
JOHNSON CREEK	YAD02	12-91	C17SW9	WS-IV
JONES CREEK	YAD01	12-31-1-7	C12NE2	C
JONES CREEK	YAD17	13-42	H18NE9	C
JONES CREEK, MIDDLE FORK	YAD17	13-42-2-2	H18NW9	C
JONES CREEK, NORTH FORK	YAD17	13-42-1-(0.1)	H18NW9	WS-II
JONES CREEK, NORTH FORK	YAD17	13-42-1-(0.3)	H18NE7	WS-II CA
JONES CREEK, NORTH FORK	YAD17	13-42-1-(0.5)	H18NE5	C
JONES CREEK, SOUTH FORK	YAD17	13-42-2	H18SW3	C
JONES POND	YAD04	12-94-7-1-2	C18NW7	C
JONESVILLE CREEK	YAD02	12-55-1	C15NE1	C
JOSHUA CREEK	YAD01	12-42-1	B14SW1	C TR
JUMP AND RUN BRANCH	YAD04	12-110-5	E16NE6	C
JUNIPER CREEK	YAD16	13-39-8-4	G20SW5	WS-III
KANNAPOLIS LAKE	YAD12	13-17-9-(1)	E16SW9	WS-III CA
KELLY BRANCH	YAD10	13-20-4-2	H17NE3	C
KENNEDY MILL CREEK	YAD07	12-119-7-2	D18NE4	C
KERNERS MILL CREEK	YAD04	12-94-12-2-(0.3)	C18NE7	WS-III
KERNERS MILL CREEK	YAD04	12-94-12-2-(1.5)	C18SW3	WS-III CA
KERR BRANCH	YAD06	12-108-21-3-1-1	E15NE7	C
KERR CREEK	YAD06	12-108-21-2-1	E16SW2	WS-II
KEY BRANCH	YAD10	13-20-4-1	H17NE6	C
KILBY BRANCH	YAD01	12-40-7	B14SW7	WS-II
KINDER CREEK	YAD06	12-108-12-1	D15NE6	C
KING CREEK	YAD02	12-63-14-1	B15SE3	C
KINGS CREEK	YAD01	12-23	D13NW3	C TR
KINGS CREEK	YAD15	13-25-7	E19SE5	C
KINSMAN LAKE	YAD16	13-39-12-11-2	H20NW7	C
KIRBY CREEK	YAD01	12-12-2	C12SE4	C TR
KRINSHAW POND	YAD16	13-48-1	H20SW5	B
LACEY BRANCH	YAD14	13-17-40-15	G17SE8	C
LADY BRANCH	YAD11	13-17-6-8	F16SE1	C
LAKE BAGGET	YAD16	13-39-5	G20SE4	WS-III
LAKE BUNCH	YAD09	13-2-3-3-2-2-(2)	E19NE1	WS-II CA
LAKE CONCORD	YAD12	13-17-9-4-2-(2)	F16NE1	WS-IV CA
LAKE CORRIHER	YAD04	12-110-1-(2)	E16SE4	WS-IV CA
LAKE FISHER	YAD12	13-17-9-4-(1)	E16SE8	WS-IV CA
LAKE LAUREL	YAD02	12-62-11	B15NW9	C TR ORW
LAKE LEE	YAD14	13-17-36-(3.5)	H16NE3	WS-IV CA
LAKE LYNN	YAD12	13-17-9-4-6-2	F16NE9	C
LAKE MAREE	YAD17	13-42-1-3-1-2	H18NE6	C
LAKE MONROE	YAD14	13-17-36-4-(0.5)	H16NE6	WS-IV
LAKE MONROE	YAD14	13-17-36-4-(2)	H16NE6	WS-IV CA
LAKE STEWART #	YAD14	13-17-36-9-(4.5)	G17SW7	WS-III CA
LAKE TILLERY	YAD08	12-(136.7)	F18SE5	WS-IV&B CA
LAKE TILLERY	YAD08	13-(1)	F18SE5	WS-IV&B CA
LAKE TWITTY	YAD14	13-17-36-9-(4.5)	G16SE9	WS-III CA
LAKE WRIGHT	YAD04	12-110-2-(1)	E16SW3	WS-II CA
LAKES CREEK	YAD09	13-2-13	E19SW7	C
LAMPLEY BRANCH	YAD17	13-42-1-1	H18NE5	C
LANES CREEK	YAD14	13-17-40-(1)	H16SE3	WS-V
LANES CREEK	YAD14	13-17-40-(12)	H17NE2	C
LANIERS CREEK	YAD09	13-2-10	E18SE6	C
LASATER LAKE	YAD02	12-90-(2)	C17SW8	WS-IV
LATHER BRANCH	YAD10	13-16-2	F18SE9	C
LAUREL BRANCH	YAD01	12-26-2	C13NW5	C TR
LAUREL CREEK	YAD01	12-24-8	C12NE6	C TR ORW
LAUREL CREEK, NORTH FORK	YAD01	12-24-8-1	C12NE5	C TR ORW
LAUREL CREEK, SOUTH FORK	YAD01	12-24-8-2	C12NE5	C TR ORW
LAYTOWN CREEK	YAD01	12-22	C12SE3	C TR
LEAK CREEK	YAD04	12-94-13-7	C18SW7	C



North Carolina Wildlife Resource Commission Information for Anson County



Public Fishing Access "Where can I go fishing without a boat?" is a question that is often asked of the N. C. Wildlife Resources Commission. Many North Carolinians do not own or have access to a fishing boat because of the expense or the storage space required. However, these people still enjoy fishing and actively participate in the sport when they can find somewhere to go fishing.



Public Fishing Access for Disabled With help from the Sport Fish Restoration Fund, a federal excise tax and import duty on fishing equipment and motorboat fuel, the Commission has developed bank fishing sites and boating access areas across the state. Some of these locations are accessible to anglers with disabilities.



The **City Lake Fishing Information For North Carolina Central Region** information concerns fishing in the central Piedmont city lakes. Municipal water supply reservoirs are an important water resource in the central Piedmont area of North Carolina. These reservoirs are located in the most densely populated areas of the state and thus receive extensive use which includes sport fishing.



The **Stream Fishing Information for North Carolina Central Region** details information pertaining to the Central Piedmont area of the state's pond and city lake fisheries. However, a less publicized aspect of the fishery in this area is stream fishing. The Central Piedmont has hundreds of miles of warm water streams supporting populations of game and nongame fishes.



The **County Fox Harvest Seasons** has information concerning open season for taking foxes with weapons during the season for taking rabbits as established by regulation by the Wildlife Resources Commission.



The Record Fishing Listing shows the North Carolina Fresh Water Fishing Records.



The Master Trout Stocking List pertains to stocking of Brook, Rainbow, and Brown Trout.



The Warmwater Fish Stocking List pertains to stocking of Channel Catfish, Largemouth Bass, Smallmouth Bass, Bluegill, Redear, Redbreast, Striped Bass, Bowfin, Threadfin Shad, Walleye, and Muskellunge.



**Public Fishing Access Areas
and Community Fishing Sites
in North Carolina**

Bank Fishing Opportunities

North Carolina Wildlife Resources Commission

Division of Inland Fisheries

The projects highlighted in this brochure were made possible because anglers and boaters pay special federal excise taxes and import duties on fishing equipment and on their motorboat fuel. The North Carolina Wildlife Resources Commission receives a share of these federal monies which is then matched with 25 percent state or other non-federal money and invested in important fishing and boating projects across the state. Without your support for the Federal Aid in Sport Fish Restoration Act, our agency's ability to provide fishing and boating opportunities in North Carolina could be severely curtailed.



Your purchase of fishing equipment and motor boat fuels supports Sport Fish Restoration and boating access facilities.



Produced by the Division of Inland Fisheries
 N.C. Wildlife Resources Commission,
 512 N. Salisbury St.
 Raleigh, N.C. 27604-1188
 Telephone (919) 733-3633.

The N.C. Wildlife Resources Commission is an equal opportunity agency.

Bank Fishing Opportunities

"Where can I go fishing without a boat?" is a question that is often asked of the N. C. Wildlife Resources Commission. Many North Carolinians do not own or have access to a fishing boat because of the expense or the storage space required. However, these people still enjoy fishing and actively participate in the sport when they can find somewhere to go fishing. Even anglers who have a boat occasionally enjoy fishing from the bank when they don't have the time or the inclination to fuel, tow, and launch their boat.

Fortunately, these people are in luck! The Commission has developed 38 public bank fishing access areas, and 21 community fishing program sites where the sport fisheries are intensively managed. Several more sites are planned for construction over the next few years. The degree of development varies among areas from simply clearing bankside underbrush to construction of fishing piers. Graveled or paved parking lots are available at most areas. Many of the facilities are accessible to persons with disabilities. Fishing is enhanced at many of these areas by the installation of artificial reefs or fish attractors and by baiting the areas with grain or fish feed to attract fish to the vicinity. Most community fishing program sites are stocked periodically with catchable size channel catfish during the fishing season. Catfish are fed several times daily by permanent solar-powered fish feeders. Fishing success at these intensively managed fishing areas varies depending on the species of fish sought, time of day and year, and all of the other variables that are a routine and accepted part of fishing.

Public Fishing Access Areas

Public fishing access areas are developed by the Commission and funded primarily through the Federal Aid in Sport Fish Restoration program from monies collected as federal excise taxes on fishing tackle and accessories. This money is matched by state funds generated from fishing license fees.

Public fishing access areas are open to the public at no cost; however, use is generally restricted to the activities associated with fishing unless noted otherwise. The mooring of boats and jet skis, swimming, and camping are among the activities prohibited at most public fishing access areas.

Public Fishing Areas by County

County	Body of Water	Public Fishing Area
Anson	Blewett Falls Reservoir	& Blewett Falls
Ashe	Chinquapin Trout Lake	& Chinquapin Trout Lake

Balsam Lake (Jackson County): From Sylva, take NC 107 South and turn left on NC 281 at Tuckasegee. Go approximately nine miles, turn left on SR 1756, and continue about five miles. The US Forest Service signs beginning at the intersection of NC 107 and NC 281 can be followed to Balsam Lake.

Fishing platforms have been constructed at several sites around the entire shoreline of this small lake, and an accessible pier has been built near the dam. This pier has a canoe loading site for persons with disabilities. Catchable size trout are stocked in Balsam Lake from March through June. This lake is a designated public mountain trout water and hatchery supported regulations apply. A special trout fishing license is required. Largemouth bass and bluegill are caught during the summer and fall. Restrooms are located at the site, and a lodge that can house small groups is available through the Highlands Ranger District office (828-526-3765).

Bell's Church (Chatham County): From US 64 east of Pittsboro, take SR 1008 North at Wilsonville. Go 1.2 miles, and the area is on the right beside the church.

Several sections of shoreline and access trails to them have been cleared of brush. Fish attractors have been established, and hardwood trees have been cut and cabled to the shoreline. Fish present include largemouth bass, sunfish, crappie, catfish, carp and Bodie Bass (striped bass x white bass hybrids). Poplar Point and Crosswinds state parks are located nearby with facilities for camping, picnicking and restrooms.

Weaver Creek (Chatham County): From US 64 east of Pittsboro, take SR 1008 South at Wilsonville. Go 3.4 miles, and area is on the right just past the intersection with SR 1972.

An area of shoreline and an access trail have been cleared of brush. Fish present include largemouth bass, sunfish, crappie, catfish, carp and Bodie Bass. Poplar Point and Crosswinds state parks are located nearby.

Rock Quarry (Chatham County): From Pittsboro, take US 64 East. Go approximately six miles, and turn left on SR 1716 (Big Woods Road). Go 4.9 miles, and area is on the right.

Brush has been cleared from several areas of shoreline along a penin-sula that projects into the lake. A graveled parking area accommodates approximately 20 cars. Largemouth bass, sunfish, crappie, catfish, carp and Bodie Bass are the primary fish available. Poplar Point and Crosswinds state parks are located nearby.

Blewett Falls (Anson County): From the intersection of US 220 and US 74 in Rockingham, take US 74 West 6.3 miles and turn right on SR 1748 (Power Plant Road). Go 2.5 miles and the parking lot is on the right just before the entrance to Carolina Power and Light Company's Blewett Hydroelectric Plant. An accessible trail leads from the parking lot to the fishing area.

An 8-foot wide barrier free concrete fishing platform is attached to the downstream wall of the power house. Anglers can fish downstream in the high current outflow throughout the 242-foot length of the power house wall. Migratory fish species, including American shad, striped bass, white bass and white perch, can be caught during the spring. Resident species such as catfish, largemouth bass and sunfish are available year round.

Brice's Creek (Craven County): From the junction of US 17 and US 70 in New Bern, take US 70 east approximately three miles and turn right on SR 1167 (Williams Road). Go approximately 1.5 miles and turn left on SR 1004 (Madame Moore's Lane). Go 1.5 miles and turn left on SR 1143 (Perrytown Road). Go 1.3 miles and turn left on Forest Service Road 121A (at sign for boating access area). Go 1.2 miles to the area on the left at the end of the road.

An accessible fishing pier is available at this site. Handicapped parking spaces are connected to the pier by a concrete walkway. Species available include largemouth bass, various sunfish, catfish, white perch

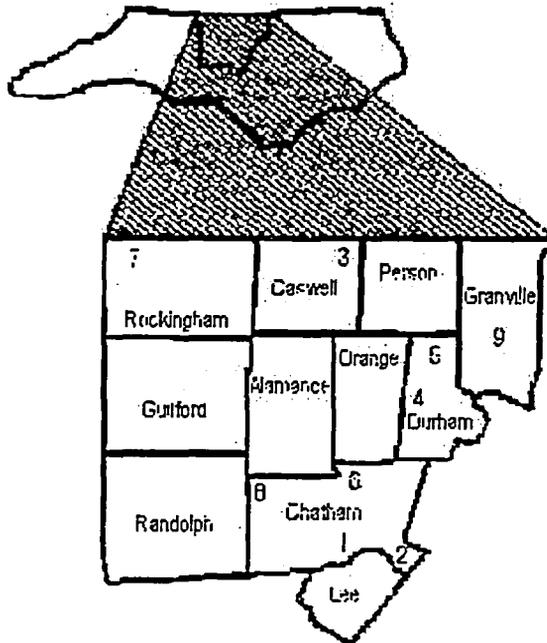
**STREAM FISHING INFORMATION
FOR NORTH CAROLINA
CENTRAL REGION**

Roger Jones, Fishery Biologist

Division of Inland Fisheries

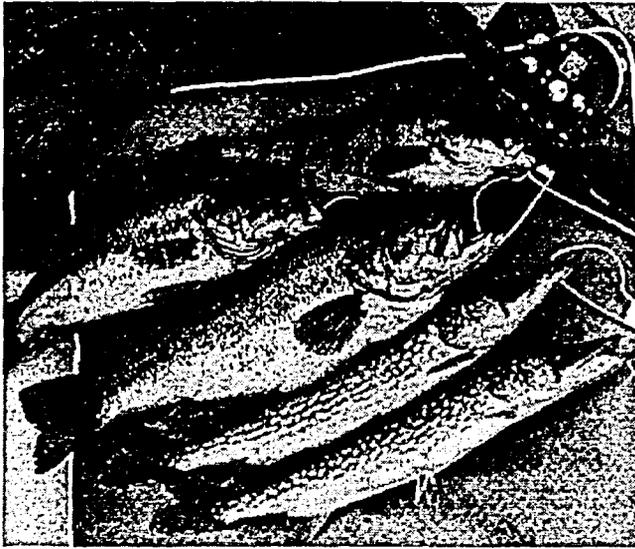
North Carolina Wildlife Resources Commission

Raleigh, North Carolina



- | | |
|--------------------|----------------|
| 1. Bear Creek | 6. Haw River |
| 2. Cape Fear River | 7. Mays River |
| 3. Dan River | 8. Rocky River |
| 4. Eno River | 9. Tar River |
| 5. Flat River | |

Introduction



Other Counties

There is no information on Stream Fishing for any other counties.

Memorandum

Date: December 28, 1999

To: File

From: Scott Ryals 
Environmental Chemist
NC Superfund Section

Subject: Fishery Usage 15-Mile Surface Water Pathway
VCC-Wadesboro
Wadesboro, Anson County, NC
US EPA ID: NCSFN 0406 924

On Tuesday, December 28, 1999, Scott Ryals of the NC Superfund Section contacted Mr. Wayne Chapman, Wildlife Enforcement Officer for District 6, at (704) 982-9255. Mr. Chapman said that he did not know of any fishing in Brush Fork, Bailey or Jones Creeks, but that the Jones and Bailey Creeks were large enough to support a fish habitat. Based on this information, and the lack of further data, the nearest fishery has been determined to be located at the confluence of Brush Creek and Bailey Creek which is approximately 3.43 miles downstream of the VCC-Wadesboro site.