# DISPOSAL OF CHEMICAL EFFLUENTS AT SALTVILLE, VIRGINIA, AND THEIR EFFECTS UPON THE NORTH FORK OF HOLSTON RIVER

By

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And
Including

# A BRIEF BIOLOGICAL SURVEY OF THE NORTH FORK OF THE HOLSTON RIVER BELOW SALTVILLE TO MENDOTA

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By

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## PRELIMINARY STATEMENT

At the behest of Mr. R. B. Worthy, Vice President of the Mathieson Chemical Corporation, the writer undertook a detailed study and review of the disposal of chemical effluents from the Saltville Plant into the North Fork of Holston River. The records and files of the Company were made available to me for study, and in addition arrangements were handled for the writer to obtain samples of effluent and of river water beginning above Saltville and extending southwestward to the head of Cherokee Reservoir at Cherokee Marina Dock, near Rogersville, Tennessee. In connection with this investigation and sampling of the river, the writer was accompanied by Mr. Harry Dunham, head of the chemical laboratory at the Saltville plant of the Mathieson Chemical Corporation. The analyses of water samples collected by the writer and Mr. Dunahm were analyzed in the company's laboratory.

The objectives of the study, as outlined to the writer by Mr. Worthy in a conference held in middle September, 1953, were (1) to develop a full and complete picture of the plant operations, particularly as they affect the disposal of effluents into the North Fork of Holston River; (2) to analyze the methods of disposal and note any possible ways by which the amount of effluent discharged into the river might be reduced; and (3) to determine at the present critical low-water stage in the

North Fork the physical, chemical, and biological character of the stream below the Saltville plant.

It should be recorded here that all information sought by the writer from company records was readily supplied, and nothing was withheld. The attitude of company officials has been very helpful to the writer in his field studies and in the preparation of this report.

After field work on the project had started, it appeared advisable to enlist the services of a qualified biologist to make a survey of the aquatic life in the stream below the plant. Accordingly, Dr. Robert Ross, Associate Professor of Biology at Virginia Polytechnic Institute, was engaged by the Company to make a survey of the stream and determine by scientific methods the true situation regarding the fish and insect life in the stream, particularly at critical places where the beauty of the stream and fishing conditions allegedly have been ruined by chemical pollution introduced at Saltville. Dr. Ross's report is attached to this memorandum as an appendix.

## Relation of the General Geology of the Saltville Area to the Quality of Water in the North Fork of Holston River

Saltville is located at the northeastern terminus of a great synclinal fold of Mississippian limestones and related saline-bearing shales, which are bordered on the southeast by the Saltville Fault. Gypsum crops out at the surface locally from Plasterco, Washington

County, northeastward for approximately 20 miles to the general area of Chatam Hill, Smyth County, Virginia. Salt marshes and seeps which are confined to the immediate area of Saltville attracted attention nearly a century ago, and these seeps were used during the Civil War to recover salt. There are no other known deposits of salt and gypsum in the interior of the southeastern United States, and largely for this reason large-scale utilization of these saline deposits has been inevitable. Local availability of high-grade limestone and short-line hauling of bituminous coal from nearby counties has favored the development of a large, diversified chemical industry whose operations include besides its large caustic plant the world's largest carbon dioxide and dry ice plant and a very large liquid chlorine plant.

The salt marshes at Saltville, now under complete control of the Mathieson Chemical Corporation, existed for countless centuries before the advent of modern settlement. The marshes served as a prehistoric salt lick which attracted a horde of terrestrial animals, including elephants, bears, sloths, numerous ungulates and rodents, remains of which have been recovered from diggings and trenchings in the Saltville marshes. Judging from the faunal lists published by Tennessee paleontologists, the entomb remains of these animals indicate beyond doubt that the saline seeps and marshes have been in existence for at least one million years.

The natural drainage of the marshy area follows the valley marked by the Company's rail line from the Norfolk and Western station and junction to the river and adjacent plant installations. Although the extent of this natural contamination by saline solutions draining from the Saltville marshes is, of course, unrecorded, it is obvious that such natural contamination has been in existence ever since the development of the topography of southwestern Virginia as we know it today. As has been concluded by Dr. Ross (Appendix), the natural ingress of saline contamination into the North Fork at Saltville has affected the fish fauna and aquatic insect fauna of the stream below Saltville for thousands of years to say the least. The peculiar localization of the salt at Saltville accounts for the fact that upstream from the town, beginning at Broddy Bottom and extending clear to the headwaters of the stream saline contamination is limited to sulphates which have been leached from exposures of gypsum. The low chloride content of the stream above Saltville is not an indication of the chemical composition of the stream in its primaeval state in that portion lying below the point of natural ingress of brine seeps at Saltville. It should be mentioned that the plant effluents now discharged into the river are not in addition to the natural pollution. Surface drainage from the salt marshes into the North Fork has been contained and used to recover salt brines from the Company's wells many of which have been in existence for more than sixty years. Natural pollution was actually abated when the Mathieson Chemical Corporation's predecessor, the Mathieson Alkali Works, began operations. Thus, to an extent not generally realized or appreciated, the North Fork of Holston River never actually existed in an unpolluted state, as some claim that it did. The geology of the Saltville area and the biological survey of the stream recently made by Dr. Ross both bear testimony to this fact.

Some of the chemical contamination of the North Fork below the Saltville Operations of Mathieson Chemical Corporation is contributed by McHenry Creek which carries away the surface drainage from the plant of the United States Gypsum Company at Plasterco, Washington County, and also the flumed mine water pumped to the surface from this company's underground workings below Plasterco. The anlaysis of the water of McHenry Creek near its mouth is given in Table 1. In addition to this downstream addition of chemical pollution to the North Fork, there are countless other places where the river comes in direct contact with the same formations of rock that contain salt and gypsum in the Saltville area. Some additional influx of chloride and sulphate salts from contacts of the river with these rock formations is inevitable and constitutes a carryover of natural pollution that existed long before the advent of human settlement in North Fork Valley.

Downstream from Saltville, the North Fork receives the waters of a host of tributaries, including some of the purest waters in western Virginia. Streams draining from the Clinch Mountain side of the valley of the North Fork down nearly to Gate City, Scott County, Virginia, are freestone waters, but below Gate City on the Clinch Mountain side of the valley and also along the entire southeastern side of the valley of North Fork the waters entering or joining the North Fork are hard. As shown in Table 2, the South Fork of Holston River is polluted to some extent, although it is farily low in chlorides and sulphates. The net effect of all the waters diluting the North Fork of Holston River is to dilute the salinity of the latter to a point where it is virtually unnoticed (Table 1).

Chemical Wastes Introduced Into the North Fork By The Mathieson Chemical Corporation At Saltville

Plate 1 shows the location of every place of discharge of waste from the diverse operations at Saltville. Beginning a description of these places of discharge with the effluents released at the river's edge beside the Dry Ice Plant, it can be directly affirmed that the steaming fluids discharging at this plant have suffered no chemical contamination in passing through the compressor jackets and cooling towers. In Table 1, analyses are given for the river water at the point of impoundment and diversion just upstream from the Dry Ice Plant and also for the river water impounded in the spray pond of raw water feed which is used for the plant's boilers. The near identity of the analyses of water samples from these two places attests the absence of chemical contamination of the river through discharge of effluent water at the Dry Ice Plant.

All of the chemical effluents of any consequence released from the Saltville operations are discharged at points B to N, inclusive, and point Q which is the principal point of release of effluents. At point B (Plate 1) a trickle of water represents drainage from the necessary washing of caustic tank cars after loading and before they leave the plant. Some additional drainage is released at B from change rooms in the caustic loading sheds. The discharge from B is not over 75 gallons per minute and the chemical contamination is very slight.

At points C and D, respectively, the "upper flume" and "lower flume" the discharge of cooling water from the caustic condensers takes place. The lower and larger flume releases a flow ranging from only a few gallons per minute up to a maximum of about 8,000 gallons of water per minute.

Under normal day-to-day operations, the water released in these flumes, which comes from the caustic condenser jackets, is pure enough to be recycled back from the flumes to the spray pond at A from which the boiler feed water is taken. As previously mentioned, the water in this spray pond has to be good to serve the boilers, and the analyses given in Table 1 show that the spray pond water is as low in dissolved solids as the river water above the Dry Ice Plant. Occasionally, however, some caustic does spill over from the condensers, in spite of every precaution, and this enters the flume lines egressing at C and D. To prevent this situation going unnoticed without immediate corrective procedures being put into action, there are automatic electrical alarm cells in each flume, which warn of the release of caustic and set into operation remedial measures that cut off the escape of the caustic into the river. As an added protection and assurance against undetected and uncontrolled pollution from spillovers of caustic into the "lower Flume" and "upper flume", the Company has installed an additional recording alarm in the middle of the river just downstream from the egress of water from point D. Thus any serious breakdown in the general area of the caustic condensers with consequent leakage of caustic into these flumes or into the river can be detected and emergency remedial measures taken before any serious damage is done.

Point E is an exit for steam escaping from the new steam drying units. There is no possibility of chemicals getting into this line.

Point F is the discharge from the "Bicarb ditch." This discharge includes the condensate and continuous blowdown of soot and fly ash from the boilers. This discharge also carries some alkalinity as a result of surface drainage from the 11% causticizing plants and storage area. Spillage of caustic solution at the storage area is held to a minimum but some spillage is unavoidable and has to be flushed away immediately for the sake of safety. This effluent yields a caustic alkalinity with a pH of about 10.3 which is offset down-stream by acidic solutions discharged from the chlorine plant at point M. The "Bicarb ditch" also carries the storm drainage off the vertical lime kiln area. It has sufficient opportunity to receive spillage from confined alkaline solutions to warrant a monitoring and warning meter, with which it is equipped. The rate of discharge from the "Bicarb ditch", except during and immediately after rains, is about 800 to 1,200 gallons per minute. The analysis of the effluent from this point F is given in Table 1.

Point G is discharge from a small sewer from change rooms in the ammonia-soda plant and bagging plant. No chemical pollution is discharged here.

Point H is the discharge of the "tower house and vat house ditch". Most of the water egressing here is water from the Company's wells, which goes through the cooling towers and condensers at the ice plant thence after addition of water from the #4 well passes through the ammonia-soda towers. The closed systems through which all the water amounting to 4,000 to 5,000 gallons per minute moves precludes the possibility of chemical contamination from the time the waters leave the source wells until discharged at point H. Consequently, there is absolutely no need for a monitoring warning signal meter on this outlet.

Below the "tower house and vat house ditch" the brine lines to the chlorine plant bridge the river. Just downstream from this crossing is a sewer which discharges water from the plants water softeners, which amounts to about 75 gallons per minute. In addition, from time to time, this point I experiences greatly increased discharge--up to 1,500 gallons per minute-----from excess and overflow of well water from the water storage reservoir in the front yard of the plant. The chemical pollution here is virtually nil.

Locality J marks the place where the still blow-off line to the muck pond comes to the surface. This line follows the route indicated by the heavy black line on Plate 1.

Point K is the old and now abandoned outlet of the sewer system for the Town of Saltville. The present outlet of the town sewer is at point L oppostite the Chlorine Plant. The high degree to which the Company has successfully confined the saline waters in the Saltville marshes is indicated by the fact that on 11 parts per million of sodium chloride was found in the sewage discharge at point L.

From M beside the Chlorine Plant a small flume discharges about 500 gallons per minute of waste water from the Chlorine Plant, which consists of general drainage in the plant but without appreciable contamination other than 30 to 40 parts per million of active chlorine. By the time the waters have reached the Henrytown bridge, all the chlorine has been consumed. It acts beneficially upon the sewage released at point L on the opposite side of the river.

From point N issues flumed drainage from Allison Gap and Perryville and also water from the salt-evaporating condensers and cooling cells in the Chlorine Plant. Sulphuric acid used to absorb water in the chlorine-gas drying towers is also discharged into the flume that discharges at point N. The amount of acid is very small, so small in fact that the effluent at N is alkaline. Negligible salt is noted in this discharge. The quantity of water released into the flume from the Chlorine Plant is 4,000 to 5,000 gallons per minute; the runoff from the Allison Gap and Perryville communities normally averages about 1,800 gallons per minute, but on October 3rd virtually no surface drainage from these villages was evidenced.

At point O the river water is monitored by an electric pH meter and a fraction of the river water is pumped from O back to the laboratory where it is analyzed every hour. These installations permit a master control of the quality of the river water as it leaves the plant and before it receives the principal effluent released from the muck pond.

The still blow-off liquors representing the residual liquor from causticizing and ammonifying of the brines produced at Saltville are piped to the east end of the muck pond where they are released as steaming hot solutions at point P. The purpose of the muck pond is to allow settling out of the $Ca(OH)_2$ turbidity and lime sludge. By comparing the chemical composition of the liquor at P and that discharged under rigid control at the gate block Q (Table 1) the function of the muck pond is obvious, sofar as promotion of settling of the lime is concerned. This is only part of the function of the muck pond. The natural discharge of the North Fork of Holston River is extremely variable, and there are prolonged periods during which the discharge is but a very small fraction of the normal flow. There are times when the river looses all visible flow and appears to be ponded. Consequently, in a large operation such as the Mathieson chemical plant, where production must go on more or less consistently, it is necessary to have sufficient storage facilities for the effluent so as to insure that the salinity in the river water below the plant and muck pond are well within tolerable limits for aquatic life. The muck pond does its good work in reducing the peak concentrations of dissolved solids in the river water below Henrytown.

The condition of the muck pond during October, 1953, indicates the enormous capacity of this impoundment to mitigate the chemical pollution at Saltville during drouths. As is well known, the current dry period has endured for more than 90 days and the river all along its course from the Broddy Bottom gaging station down to Cherokee Reservoir is reduced to a near-record low discharge. Even so, the water level in the muck pond on October 3 was about 10 feet below the maximum.

This pond put into operation in 1925 after failure of an older and smaller pond had an original area of 63 acres, was subsequently raised in capacity by heightening the muck dam about 35 feet to give storage area of 70 acres, and will be within the next two years raised another 10 feet to give a storage area of 77.3 acres. The enlargement of this pond has greatly increased its period of usefulness, which still has many years to go. The capacity of the reservoir has proved to be far more than ample to handle continuous impoundment of effluent for such periods as twenty-eight years' experience has found necessary. Sometimes during a heavy rain or thereafter, it is necessary to impound and retain temporarily all the effluent until the milk of lime ooze stirred up by inrushing storm waters from off the mountain-side has settled again to the bottom. The effluent leaving from Q is clear and is principally a solution of calcium and sodium chlorides, minor sulphates, and possessing methyl orange alkalinity.

About 2,000 feet downstream from point Q is a continuous recorder that plots the salinity of the solutions after they have mingled with the river water below the Hanrytown Bridge. The accuracy of the electric metering device is checked at frequent intervals on a continuing basis during day and night by titrations made in a shed by the electirc cell at R. As a further check, more detailed chemical analyses are made on samples taken at R and sent to the laboratory at the plant. The chemical composition of the river at R, as sampled on September 24, 1953, is shown in Table 1.

The regulation of the discharge from the muck pond is an extremely delicate operation. The blocks regulating the height of water is impounded in the pond can be controlled down to about 1/8 inch. Considering the corrosive nature of the impounded fluids, jamming of the blocks from deterioration of metal parts should be troublesome. Indeed it would be if the operating mechanisms were controlled by servomechanisms and not by hand. Much more delicate adjustments can be made manually than could ever be done otherwise. In a complex chemical operation, power failures are not uncommon. It would be extremely hazardous to entrust to the vagaries of electric power the most important and delicate operation affecting the chemical control on the North Fork of Holston River. An automatic control of the blocks at Q, based on salinity and alkalinity of the river at Henrytown would be unworkable. During rainy spells, the monitor would call for an increase in release of ponded effluent because of the increased dilution produced by storm run-off. But at the same time, the pond becomes turbid with milk of lime so as to make it unsuitable for release into the river. A salinity and alkalinity meter within the muck pond, controlling the release of solutions is, of course, wholly impractical because the flow of the river varies so greatly that from day to day and week to week adjustments in rate of release of effluent from point Q have to be made despite continuously increasing salinity and alkalinity. Actually, the decision to impound completely or change the rate of discharge from point Q must be arrived at only after interpreting several factors (some of which are antithetical) in the light of 28 years of operating experience. No servomechanism can be trusted to do this all-important job. The policing job done by plant personnel on the chemical quality of the river leaving Henrytown is one of the truly remarkable phases of the Saltville operations.

## Reduction of Chemical Pollution At Saltville

Pollution abatement is naturally a primary consideration in the Saltville operations. The limits of tolerable pollution are fairly well defined. If pollution can be lessened at any point, it minimizes the tremendous job of policing the quality control of the river water leaving the plant. If constant attention were not directed toward reduction of pollution at every point, the growth of the entire operation would have ceased years ago. Pollution has been reduced.

Since the new muck pond was put into operation three lime recovery kilns have been built--two in 1930 and one completed in 1947--which reduce by possibly 400 tons per day the lime suspensoid entering the muck pond. Of much greater importance is the development by the

Company of an enormous supply of fresh water from a field of wells. The big well field at Broddy Bottom yields not only water for many plant purposes but also part of the drinking water at Saltville. The combined flow of the Company's water wells is between 8 and 10 million gallons per day, as shown in Table 3.

The tremendous benefit of this supply of well water can be reckoned by comparing it with the low discharge of the North Fork of Holston River which it serves to dilute and thereby reduce the pollution. At times of exceedingly low water in the North Fork the discharge is reduced to about 20 million gallons per day. Thus the groundwater supplies developed by the Company have served to reduce pollution by augmenting the minimum discharges of the river during drouths by as much as 50 per cent. The beneficial effects of this well water have not yet been fully achieved, because there are good possibilities for increasing the groundwater supplies for the plant by 50 to 60 per cent by addition of new wells in suitable locations.

The recency of this development can be judged from the fact that 70 per cent of the groundwater from Broddy Bottom has been and is being taken from wells drilled during the past 5 years. The care and detail which the Company has exercised in probing the resources in the Saltville area can be appreciated by noting that brine wells yielding the raw feed for the plant's operation are only a mile from the main sources of supply of good well water. The delicate control of operations necessary to protect the chemical integrity of both the brines and the vast quantities of fresh water--to prevent one from contaminating the other signalizes the Company's constant concenn for quality control of all waters entering and leaving the plant.

Chemical pollution, quite to the contrary of belief in some quarters, has been and is being controlled and reduced in the Saltville operations.

The still blow-off liquors from the ammonia-soda operations average 1400 gallons per minute. The alkalinity of the entering solutions in the muck pond is about 2.5 to 3.0 titer; that of the fluids released from point Q are about 0.7 titer (Table 1). This liquor is the left-over solution after all the ammonia in the plant operations has been freed by precipitated lime or calcium hydroxide. The little quantity of sodium chloride in the still blow-off liquors represents the necessary excess of brine that must be carried into the ammonia-soda operations in order to assure efficient recovery of substances manufactured from the brine. The only way to reduce the amount of dissolved solids constituting the chemicals released into the river, so largely contributed from the still blow-off liquors, is to reduce the production of the plant or increase the supply of groundwater ultimately released after use for cooling purposes in the plant to augment the flow of the North Fork and thereby dilute the effluents that have to be discharged into the river. With salt in such short supply in the southeastern United States, the Company will in the future, just as it has been in the past, be pressured to increase production and not decrease it. As rapidly as possible, the Company is undertaking the careful explorations necessary for eventually exploiting to the fullest possible extent the tremendous and constantly rechargeable supplies of ground water for augmenting river flow and thereby reducing chemical contamination inthe river. The Mathieson Chemical Corporation is, it is safe to say, the largest consumer of potable groundwater of any single industry in western Virginia, and the Company can be depended upon if for no other reason that its own interests to explore fully and develop to the maximum extent the groundwater supplies of its area.

The near record-breaking drouth and consequent sharp decline in discharge through the North Fork below Saltville, which is now being experienced, is an excellent time to examine the degree of pollution and compare it to that of former years. During such a drouth, the chemical contamination is greater than at any other time. The existing conditions, therefore, are about as unfavorable as they could expectably be over a long period of time. Table 4 shows the dissolved solids in the North Fork at strategic places below Saltville and compares them with the published analyses of samples from the same places collected in former years and published in reports of the Tennessee Valley Authority. All the analyses cited are from samples collected during low water conditons. The data supplied in this table supply a ready answer to the perennial question about the supposed increase of Mathieson's pollution of the North Fork of Holston River. The degree of pollution is of the same approximate magnitude as in former years.

## Is The Pollution From Saltville Objectionable?

In answering this question it is necessary to classify the complaints of the small but vociferous minority who claim that it is objectionable and intolerable. The objections center around; (1) claims that the beauty of the stream has been destroyed; (2) that the water in the river has been rendered unfit for use; and (3) categorical statements that fishing has been ruined by chemical pollution and that the situation is getting worse.

The writer's work as a field geologist in western Virginia has provided opportunity for him to traverse most, if not all, of the major streams and rivers of the Appalachian Valley from Winchester, Frederick County, all the way to Cumberland Gap, Lee County, Virginia. From the mouth of Wolfe and Logan Creeks, at the crossing of State Highway 80, below Saltville, all the way to the mouth of the North Fork in the western environs of Kingsport, Tennessee, the North Fork is as physically attractive, as free of objectionable sediment and suspensoids, and as beautiful as any other stream flowing through limestone country. Bank conditions are good, and from all appearances the North Fork is the same today as it was when the writer first traversed its banks from Mendota to Gate City in the middle "thirties.

Claims have been made that the river water several miles below the plant is harmful to livestock, that it brought about rapid deterioration of mortar when used in preparing mortar mixes for masonry, and that the quality of the river below Saltville has adversely affected the possible development of industrial sites. To answer these arguments, it is advisable to emphasize the exact nature of the chemicals put into the water at Saltville. The ingredients present in appreciable and significant quantities are: (1) calcium chloride, (2) sodium chloride, (3) calcium sulphate, and a certain amount of alkalinity.

Concentrations of calcium chlordie, even such as exist at Henrytown Bridge, in the North Fork are far below the levels known to have been harmful to game and livestock (Heller and Larwood, 1930). All but one of 12 documented reports of fish kills by calcium chlordie involve concentrations of calcium chloride greater than that which prevails at Henrytown (McKee and others, 1952, p. 201). The concentrations of sodim chloride are far below tolerable limits for humans, livestock, poultry, and fresh-water fishes (McKee and others, 1952, p. 362; Anderson, 1948, p. 96). Fifteen studies of supposed ill effects and in some instances deaths of fish life from sodium chloride in fresh water, tabulated by McKee and others (1952, p. 364) deal with concentrations two to thirty times greater than the sodium chloride content noted even at the Henrytown Bridge during the present low water level. The alkalinity of the North Fork of Holston River is virtually negligible, as is attested by the pH values of the river water samples (Table 1). As well summarized by McKee and others (1952, p. 362-365; 200-202, 244-249), the definite instances where high concentrations of calcium chloride, or sodium chloride, or alkalinity has been established to have been detrimental to livestock, poultry, or fish populations have involved concentrations far above those prevalent at Mendota where, so it is reported, the effects of dissolved salts have been most objectionable.

It is true that the water in North Fork is too saline, as far southwest as Kingsport, Tennessee, for some industrial uses, but the composition of the water as determined from samples collected at Weber City and Rotherwood indicate general suitability of the water for most industrial purposes, except boiler feed.

It has been alleged that river water below Saltville has caused concrete mortar to deteriorate. It is common knowledge that both sodium chloride and calcium chloride are recommended for addition to Portland cements in making concrete under various temperature conditions. Concentrations of 2% calcium chloride have been found (Solvay Sales Division, Allied Chemical And Dye Corp. Pamphlet:

"Effects of Calcim Chloride on Portland Cement") to accelerate set, give added early strength, promote curing, facilitate air entraining, increase workability, and add materially to ultimate strength of mortar and cement. Any claims that either sodium chloride or calclim chloride in the waters of the North Fork has caused deterioration of concrete are controverted by know facts established by careful tests and experiments.

Table 1 shows the amazing decline in salinity of the waters of the North Fork of Holston River below Saltville. The stream recovers rapidly below the mouth of Wolfe and Logan creeks, and although the chloride concentrations at Mendota are farily high, the river is most certainly normal in appearance, and it is, as Dr. Ross has determined from his survey possessed with a thriving population of fishes. (See Appendix)

Fish and insect life are, after all, among the dominant measuring guides for pollution in Virginia streams. Such features are much more tangible than conclusions that a stream is unfit for use of a particular industry. Therefore, it was felt that the real key to the proper understanding of the degree of pollution and its attendant effect upon the North Fork of Holston River could only come from a detailed scientific study in the field of the fish population and aquatic insect life. The study made by Dr. Ross completely refutes the reckless charges that have been made recently to the effect that effluents from the Saltville plant have ruined the fishing in North Fork.

## Summary

The studies made by the writer indicate that the following conclusions can be made without equivocation:

(1) the North Fork has been throughout its history a chemically polluted stream;

(2) the still blow-off liquors containing large amounts of calcium chloride, sodium chloride, and some alkalinity, and minor amounts of sulphates, have to be disposed of and cannot be permanently impounded or evaporated or otherwise withheld from surface drainage;

(3) the amount of chlorides in the still blow-off liquors can be reduced by only two methods; (a) curtailment of production , or (b) development of additional fresh ground water which can be released into the river to dilute the effluent during low water stages;

(4) that the Mathieson Chemical Company, while obviously not interested incurtailing production, has at the same time expended large sums of money and conducted extensive surveys in an attempt to increase its supplies of fresh water for plant use and for dilution of the effluent turned into the river from the muck pond;

(5) that the Mathieson Chemical Company has instituted a system of protective measures and alarm systems adequate to meet eventualities involving break-downs at the plant;

(6) that the Mathieson Chemical Corporation has not slackened its efforts to control and wherever possible abate pollution in the North Fork;

(7) that the North Fork is essentially the same as it has been

for the past 25 years, sofar as physical conditions of the stream are concerned;

(8) that concentrations of chemicals in the river water not far below the plant, say for example beginning at the mouth of Wolfe and Logan creeks, are certainly far below those that have been determined by scientific study to be objectionable or dangerous to humans, livestock, poultry, or fishes;

(9) that the Company is using the same muck pond it has been using for 25 years or more without having by any means exhausted the usefulness of this pond; and

(10) that the present methods of controlling the outlet of fluids from the pond and other checks and rechecks of the quality of the river at various points through the plant and below the muck pond--all of which require costly expenditure of personnel for the manual operations involved --are far superior to any devised system of servomechanisms or auto--matic controls that depend upon the vagaries of electrical power in any and all instances.

Additional Comments

Possibilities for developing additional supplies of fresh ground-water for plant use are sufficiently good to warrant drilling of more wells. Periodic sampling of the river all the way down to the head of Cherokee Reservoir should be continued. Biosurveys like that made by Dr. Ross (Appendix) should be made annually for the future protection of the Company against unfounded and reckless reports of damage being done by discharge of effluents into North Fork from the operations at Saltville. This year's survey, heartening though it is to all lovers of good and beautiful streams, will not be a conclusive argument against such claims if raised again next year.

The writer is continuing his general assignment of considering all the possible angles of the waste disposal problem at Saltville, but there is little prospect of any major discovery that will warrant significant modification of present practices and procedures. The writer's study convinces him that much more expenditure of personnel for policing the disposal of wastes at Saltville has been made than is generally realized. Far from being careless or negligent, the Mathieson Chemical Corporation has quite evidently done a consistently good job in regulating its waste discharge and is anxious to keep the North Fork of Holston River in the best possible condition for downstream uses, including fishing.

Submitted In Duplicate (Signed) Byron N. Cooper
October 18, 1953

Table 1.-Analyses of samples of river water and plant effluents at various places from North Holston, Smyth County, Virginia, to the head of Cherokee Reservoir near Rogersville, Hawkins County, Tennessee.

| Location of Sample | pH | Chemical Composition (In Parts Per Million) | | | | | Date Collected | |
|---|---|---|---|---|---|---|---|---|
| | | Ca | Mg | Na | Cl | $SO_4$ | | |
| River bridge just above North Holston, Va. | — | — | — | | — | 10 | 10-3-53 | TENN Sta No. 1 |
| Broddy Bottom Bridge east of Saltville | 8.50 | 40 | 9 | 0 | 0 | 24 | 9-25-53 | Sta No 2 |
| Intake of river water above Ice Plant Bridge | 8.50 | 42 | 8 | 0 | 0 | 24 | 9-25-53 | |
| Spray pond at Pumping Station (Point A) | 8.60 | 38 | 10 | 0 | 0 | 48 | 9-25-53 | |
| Bicarb Ditch (Point F) | 10.3 | 76 | 14 | 6 | 36 | 113 | 10-3-53 | |
| Entering still blowoff liquor (point P) | 11.3 | 44400 | 356 | 950 | 97270 | 2877 | 10-3-53 | |
| Discharge from muck pond at Point Q | 11.2 | 41400 | 4 | 981 | 106500 | 786 | 10-3-53 | |
| Henrytown Bridge (R) | 7.15 | 2415 | 26 | 1472 | 6525 | 134 | 9-25-53 | Sta. No 3 |
| McHenry Creek just above mouth of stream | | 356 | 29 | | Trace | 823 | 10-15-53 | |
| State Highway 80 Bridge near Logan Creek | 7.55 | 1784 | 24 | 1357 | 5213 | 125 | 9-25-53 | Sta. No 4 |
| U. S. Route 19 Bridge at Holston, Va. | 7.63 | 1303 | 19 | 1012 | 3847 | 96 | 9-25-53 | Sta No. 5 |
| Route 615 Bridge near Mendota, Va. | 7.68 | 1293 | 18 | 966 | 3723 | 86 | 9-25-53 | Sta No. 6 |
| U. S. Route 23 Bridge Weber City, Va. | 7.72 | 792 | 14 | 529 | 2216 | 62 | 9-25-53 | Sta No. 7 |
| Mouth of North Fork west Kingsport, Tenn. | 7.45 | 265 | 7 | 161 | 691 | 38 | 9-25-53 | Sta No. 8 |
| Iron Bridge, Church Hill Tenn., se. of town | 7.70 | 48 | 4 | 0 | 71 | 34 | 9-25-53 | Sta. No. 10 |
| Head Cherokee Dock at Cherokee Marina Dock | 7.80 | 42 | 9 | 0 | 35 | 29 | 9-25-53 | |

Table 2.- Analyses of samples of water from the North and South Forks of Holston River in Virginia and Tennessee.

| Location of samples | pH | Ca | Mg | Na | Cl | $SO_4$ | Discharge Sec. Ft. | Date |
|---|---|---|---|---|---|---|---|---|
| | | Chemical Composition in PPM | | | | | | |
| Old iron bridge near Church Hill, Tennessee | 7.5 | 61.4 | 8.0 | 25.2 | 88 | 28.8 | 2,090 | 9-37 |
| North Fork of Holston River, Rotherwood, near Kingsport, Tennessee | 7.6 | 214.4 | 7.4 | 161.6 | 578 | 14.5 | 400 | 9-37 |
| South Fork, below Kingsport, Tennessee | 7.5 | 31.2 | 7.6 | 12.2 | 6 | 33.1 | 2,300 | 9-37 |
| North Fork, near mouth, Rotherwood, near Kingsport, Tennessee | 7.45 | 265 | 7.0 | 161 | 691 | 38 | 350* | 9-53 |
| South Fork 1.4 miles east of Rotherwood, near Kingsport, Tennessee | 7.47 | 32 | 4.0 | 0 | 17 | 43 | 1,900* | 9-53 |

* estimated flow.

Table 3, -Average yields of water wells operated by the Mathieson Chemical Corporation.

| Well Name or Number Numbers on Plate 1 | Location | Gallons Per Minute |
|---|---|---|
| No. 1 | Broddy Bottom | 1,008,000 |
| No. 4 | Dry Ice Plant | 3,600,000 |
| No. 5 | Broddy Bottom | 720,000 |
| No. 6 | Broddy Bottom | 252,000 |
| No. 7 | Broddy Bottom | 432,000 |
| No. 8 | Broddy Bottom | 936,000 |
| Cardwelltown | Allison Gap | 1,080,000 |
| | Total | 8,028,000 |

Table 4.-Analyses of river water samples taken in September, 1953, compared with analyses of samples from the same places during comparable low-water stages of previous years, as determined from published records of the Tennessee Valley Authority.

| Description of places where samples were taken | Chemical Composition In PPM Ca | Mg | Na | Cl | $SO_4$ | pH | Date Collected |
|---|---|---|---|---|---|---|---|
| From upstream side of old iron bridge on Route 615, 3/4 mile southwest of Mendota, Virginia | 1065.6 | 29.7 | 620.8 | 2859 | 62.6 | 7.6 | 8-4-44 [1] |
| | 1222 | 3.6 | 1631.16 | 2664 | 66.61 | 7.7 | 9-28-44 [1] |
| | 1293 | 18 | 759 | 2996 | 77 | 7.92 | 9-25-53 |
| From river's edge just above mouth of North Fork at Rotherwood, west of Kingsport, Tennessee. | 214.4 | 7.4 | 161.6 | 578 | 14.5 | 7.6 | 9-37 [1] |
| | 223.2 | 11.6 | 156.7 | 565 | 15.4 | 7.6 | 10-37 [1] |
| | 265 | 7.0 | 161 | 691 | 38 | 7.45 | 9-25-53 |
| Upstream side of old iron bridge southwest of Church Hill, Tennessee | 57.1 | 7.4 | 39.3 | 106 | 29.1 | 7.7 | 9-37 [2] |
| | 61.4 | 8.0 | 25.2 | 88 | 28.8 | 7.5 | 9-37 [2] |
| | 93.8 | 11.14 | 52.44 | 171 | 58.80 | 7.5 | 11-6-46 [1] |
| | 48 | 4.0 | 10 | 71 | 34 | 7.7 | 9-25-53 |

1/ Industrial Water Supplies of the Tennessee Valley Region, TVA Div. Water Control planning Publ., June 1948.

2/ Studies of the Pollution of the Tennessee River System: Health and Safety dept., TVA, by G. R. Scott and S. L. Jones.

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awp

DISPOSAL OF STILL BLOW-OFF LIQUORS AT THE SALTVILLE OPERATION OF THE MATHIESON CHEMICAL CORPORATION, SALTVILLE, VIRGINIA

This memorandum replies to an inquiry concerning the possibilities for disposal of the still blow-off liquors from the Saltville operation into underground caverns instead of being released into the North Fork of Holston River in the vicinity of Henrytown, as is now being done under controlled conditions.

In order to make an adequate reply to this inquiry, it is necessary to consider the nature of the effluent solutions that are involved in the disposal problem at Saltville. The still blow-off liquors contain about 13% chlorides, of which about two-thirds is calcium chloride and one-third sodium chloride. Calcium carbonate and calcium hydroxide are present in quantity sufficient to produce a PH of approximately 13. The quantity of the effluent amounts to 1,200 to 1,500 gallons per minute. The North Fork of Holston River flows on limestone and dolomite rocks all the way from the Broddy Bottom well field located a mile or so northeast of Saltville to Henrytown where the effluent solutions are impounded for controlled release into the river. Sinkholes abound in the area between Henrytown and Broddy Bottom, particularly in the knobs country between Holston River

Plasterco-Saltville-Maccrady highway. Another belt of limestone and dolomite occurs in the hilly area between the brine-well fields at Saltville and the village of Quarry situated on McHenry Creek. Any contemplated disposal of waste liquors into underground caverns would involve disposal of the solutions into sinkholes existing in one or the other of these two belts of calcareous rocks.

It would be wholly impossible to dispose of the effluent solutions into any sinks and caverns in the limestone-dolomite belt near the plants of the Saltville Operation and thereby reduce the industrial polution of Holston River. The sinkholes in the area between the river and the Plasterco-Saltville-Maccrady road certainly drain directly into Holston River. Indeed, it is the seepage of groundwater through sinks and underground solution holes into Holston River that maintains the surface discharge of the river between periods of rainfall. If effluent solutions were pumped into some of these sinks the solutions would drain directly back into Holston River under conditions that would not permit control of the situation, such as is now in effect through use of the plant's effluent basin and controlled disposal system. The effluent solutions could not be discharged into any solution holes or caverns at or below river level because any openings in the rocks that exist there are surely full of water. Even if it were possible to dispose the chloride waters underground in the vicinity of the plant, to do so would surely contaminate and render utterly useless the only source upon which the Company and Town can utilize for drinkable and potable water. The Saltville Operations depend upon large quantities of groundwater of low mineralization for use in various sections of the plant. If the still blow-off liquors were forced into underground fractures or solution holes, the effect would be to increase beyond tolerable limits the dissolved solids present in the groundwaters now being pumped from numerous wells located on this belt of limestone and dolomite. The close proximity of the limestone-dolomite belt to Holston River means that waters moving into sinks and downward to the river travel a very short distance along a relatively straight line of descent before emerging again at river level. Hence, the same quantity of chemical effluent would find its way into the river as was dumped into the sinkholes, and the short distance of underground travel would not permit appreciable dilution of the effluent before the solutions became part of Holston River. Thus, it can be said that disposal into sinkholes in the limestone-dolomite belt near the plant would not only offer absolutely no improvement over the present arrangement but would jeopardize the sources of groundwater upon which the plant and Town depend so heavily. Under no circumstances would it be advisable to force the effluent underground anywhere near or below river level.

The only other belt of cavernous rock that might be considered anywise possible as a disposal area is the one situated between Saltville and Qaurry village. Sinkholes abound in this area, which is situated 100-500 feet above the brine ponds at Saltville. This limestone belt is bounded on the north by the Saltville overthrust fault, a major dislocation in the strata which has thrust the limestones and dolomites upon the red Maccrady formation which underlies the Town of Saltville. Most of the water entering the numerous sinks in the limestone south of the Saltville fault in the hilly area south of Saltville percolates downward to and thence laterally along the buried fault plane to some point of emergence along the side of a deep gully such as the valley of McHenry Creek or the gully directly south of McKee Hospital. At such points there are quite commonly large springs, many of which are utilized for domestic water. The very large spring along the highway in the valley of McHenry Creek is the source of water for the Town of Plasterco. It would be possible to dispose of large quantities of water into sinks in the hilly area south of the Saltville fault, between Saltville and Quarry village, but to do so would surely contaminate many if not all of the springs in that area that are now being used for domestic water. Certainly the costly expense of laying a line for disposal of effluents into sinks south of and above the town of Saltville could nowise be justified in face of the strong probability of contaminating important sources of domestic water now being utilized in the vicinity.

There are no other possible areas for disposal of chemical effluents into underground caverns in the vicinity of the Saltville Operations. In view of the geological conditions existing in the Saltville area, it seems to me to be entirely inadvisable to consider it feasible or anywise beneficial to dispose chloride-bearing solutions from the plant into underground cavities or solution holes near Saltville. In my opinion, the disposal of the effluent solutions into Holston River under controlled conditions is the best and most satisfactory method that could be used under the circumstances prevailing in the Saltville area. There are some areas in southwestern Virginia, where underground disposal of chemical effluents can be considered highly desirable, but in such areas the general topographic setting and pertinent geological conditions are very different from those prevailing at Saltville.

Respectfully yours,

(Submitted In Triplicate)

January 3, 1953

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February 14, 1953

SUPPLEMENTARY MEMORANDUM ON POSSIBILITIES FOR
UNDERGROUND DISPOSAL OF CHEMICAL EFFLUENTS
NEAR SALTVILLE, VIRGINIA

In an earlier memorandum, important geological considerations were outlined, which make it absolutely infeasible to attempt to dispose of chemical effluents from the Saltville Plant into underground openings in the rock at elevations above or slightly below the general elevation of operations at Saltville. It was pointed out that disposal of the waste solutions into solution cavities in the sinkhole country situated between the Saltville-Plasterco road and Holston River would be unsatisfactory because of the very short lateral and vertical distances the waste solutions would have to travel to get back into Holston River. It was emphasized that the solution cavities in the limestones in this belt had been made by shallow percolating waters seeking a more direct route to Holston River than that provided by surface tributaries crossing the sinkhole country. It was also pointed out that disposal of the chemical effluents into shallow wells would surely lead to contamination of the supply of fresh water upon which the Saltville Plant and Town of Saltville depend for water. Possible disposal of the effluents into sinkholes and solution caverns south of the Saltville fault was considered inadvisable and impractical because of the certainty of contaminating springs, such as the large one along McHenry Creek, which supplies Plasterco with water. In all three of the areas that were previously considered, the obvious wholesale movement of ground-water indicates circulation toward and connections with surface streams flowing at relatively inferior elevations. Disposal of effluents into any of these three types of situations in the Saltville area would lead to movement of the solutions into the drainage of Holston River, which would defeat the purpose of the disposal of the waste solutions into underground openings in the rock.

Part of the infeasibility of disposal of the plant effluents in any one of these situations is the chemical nature of the effluent itself. If the effluent contained some milky suspension of finely divided solids that would set up or harden in the course of underground transit, the contamination problem would be easy to solve. But in the case of the high-chloride effluents from the Saltville Plant, the material is largely dissolved and cannot be separated from the solutions except by evaporation which of course is impossible by underground disposal of the solutions.

It is, of course, absolutely impossible to envision disposal of the plant effluents into the large cavities in the Maccrady formation, which are created by leaching out the salt and pumping out the brine for plant consumption. The operation of the Saltville plant depends upon maintenance of a brine feed of known concentration, which can only be obtained by using potable water as the dissolving agent. Considering the small size of the brine field, the introduction of effluents into any of the cavities created far underground by leaching out of the buried salt would almost certainly prove diastrous.

Disastrous to whom or what? WMM

The possibility for disposal of the chemical effluents from the Saltville plant into deep underground reservoirs through specially drilled disposal wells needs to be considered in the light of the general feasibility of such disposal assuming that deep underground reservoirs exist beneath the Saltville area and also in the light of the geological conditions that probably prevail at depth which would determine whether such reservoirs are at all likely to exist at depth.

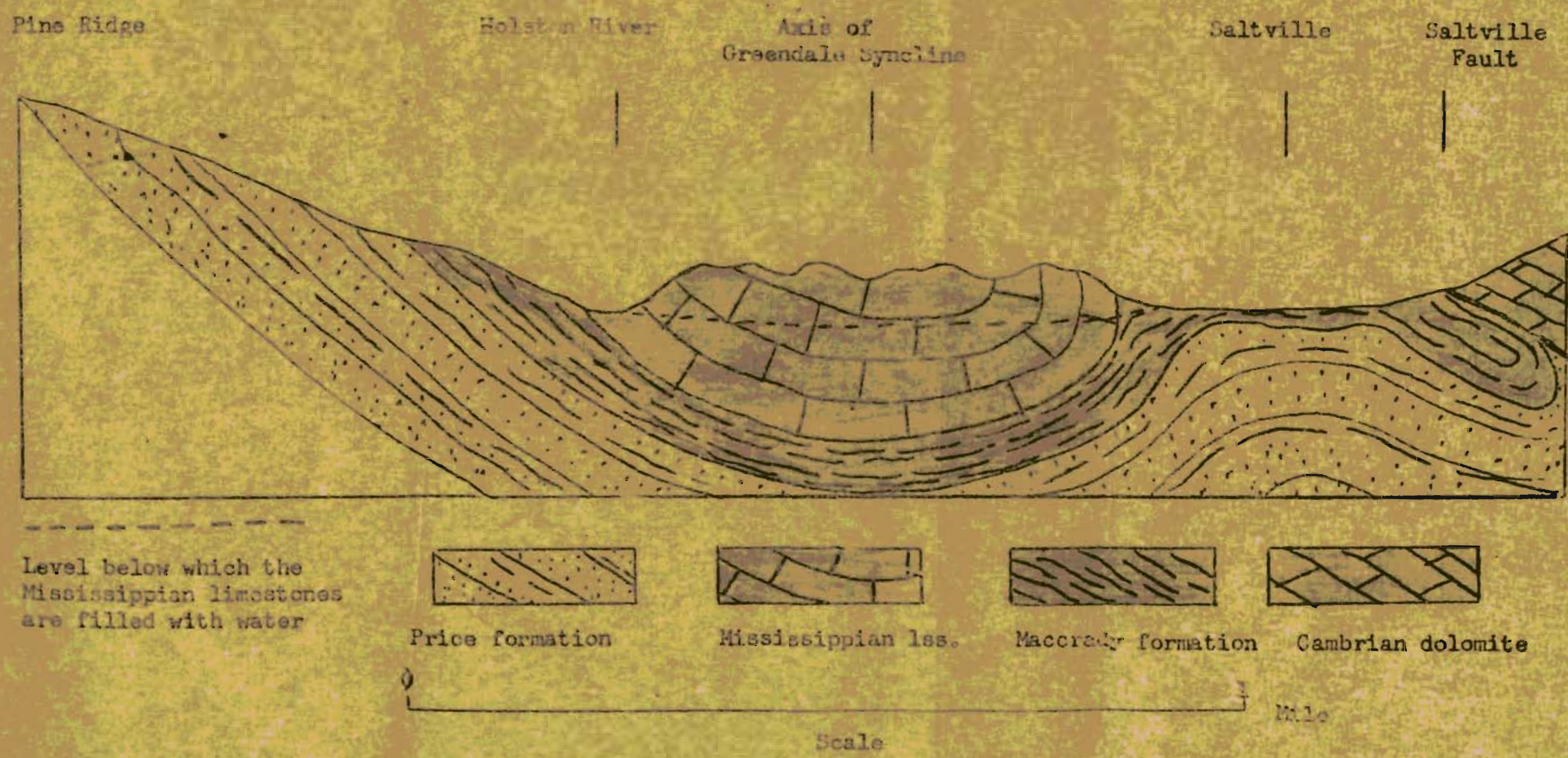
The limestone bedrocks that contain the solution cavities and sinkholes in the territory between Holston River and the Saltville-Plasterco road are underlain by the following rock formations, in descending stratigraphic order: (1) Maccrady formation, about 450 feet thick and composed of impervious mudstone, salt, gypsum, and some anhydrite; (2) Price sandstone and shale, about 1,000 feet thick and composed of dense, tightly cemented beds through which little or no water can move; (3) Devonian shales and sandstones, about 2,500 feet thick and composed of dense fissile rocks that are virtually devoid of porosity and permeability; (4) Huntersville flint, about 65 feet thick and with a dense glassy texture; (5) Rocky Gap sandstone, 75 feet thick and probably porous and permeable; (6) Clinton and Clinch formations, about 475 feet thick and composed chiefly of extremely hard massive impervious quartzite with minor red sandstone and variegated shales none of which would be permeable; (7) Juniata sandstone, about 400 feet thick, impervious, shaly; (8) Martinsburg formation, impure limestone and calcareous shale, about 1,400 feet thick, probably very impervious; (9) Moccasin formation, 450 feet thick, very impervious; and (10) a thick succession of limestone and dolomite, several thousand feet thick, which may be somewhat fractured and broken.

In this succession, the only bare possibilities for encountering porous or fractured zones in which any appreciable quantities of fluids might be stored are in the Rocky Gap sandstone and the much more deeply buried limestones and dolomites below the Moccasin formation. The fact that the Rocky Gap sandstone crops out several hundred feet above the Saltville Plant northwest of Pine Ridge may be an indication that this possibly porous formation is actually an aquifer which carries water under considerable hydrostatic head where deeply buried under the Mississippian limestones near the Saltville Plant. The possibility of fracture spaces of any great extent in the limestones and dolomites under the Moccasin formation might be doubted, because in the only deep test well sofar drilled into the folded beds of southwestern Virginia---the California Company's dry hole drilled on Price Mountain near Blacksburg--- at depths below 4,000 feet and down to 9, 363 feet (bottom of hole) all of the fractures in the rocks were completely filled with mineral matter. Thus it must be concluded that in the Saltville area, the possibilities for deep disposal of effluents from the Saltville Plant are virtually nonexistent.

The very deepest stratigraphic zone where solution cavities and other openings in the rock could be expected to exist is the bottom part of the Mississippian limestone succession in the Greendale syncline which is bounded in a general way on the surface by Holston River and the Saltville-Plasterco road. As shown in the accompanying sketch, the Mississippian limestone succession is underlain by a very thick aggregation

GENERALIZED GEOLOGIC SECTION IN THE VICINITY

OF SALTVILLE, VIRGINIA



of shales and sandstones which prevent further downward movement of water. Inasmuch as the Mississippian limestones lie hundreds of feet below the Holston River in the bottom of the Greendale syncline, any water that descends to this position would be trapped and would be static. With Holston River so close at hand, there has been every opportunity for egressing river water to seep into the folded Mississippian limestones and fill completely to the general level of the river itself all the openings in the buried limestone beds in the trough of the Greendale syncline. Therefore, the only openings into which any introduced fluids can be expected to move are those in the beds which crop out above the elevation of the river. This explanation supports my previous conclusion that the disposal of effluents into any of the sinkholes in the land between the river and the Plasterco-Saltville road would leak directly into the river and would not be stored.

In summary, it can be said that all the geological indications in the Saltville area indicate that the openings in the bedrock which could conceivably take any appreciable quantity of industrial effluent would be restricted to the limestones which crop out above river level. Deeper fractures are certain to be full of water, and the existence of porous and fractured reservoir space in the more deeply buried formations is either to limited or too remote to be a feasible consideration.

Underground disposal of effluent solutions has attracted unfavorable comment in many quarters. In an attempt to discover whether underground disposal of industrial wastes had met with much success, the writer sent inquiries to persons in authority, who have had full opportunity to study this problem for several years. Among those consulted were: Mr. B. C. Moneymaker, Chief Geologist, Tennessee Valley Authority, Knoxville, Tennessee; Mr. A. N. Sayre, Chief, Ground Water Branch, United States Geological Survey, Washington, D. C.; Mr. Norman Billings, Chief, Hydrology Division, Water Resources Commission, Lansing, Michigan; and the Ohio State Geological Survey staff, Columbus, Ohio. Literature on underground disposal is virtually limited to a few discussions dealing with disposal of wastes into shallow, flat-lying beds. In such conditions, the movement of underground waters can be predicted with confidence and subsurface tracing of the routes of water travel can be done through use of observation wells. Folded strata introduce many additional complexities and uncertainties which make underground disposal hazardous except in certain localized areas where the volume of open crevices and fractures above the water table is large. Except in areas where cavernous rock occurs on or very close to a drainage divide, the volume of open crevices in the bedrock is apt to be very small, and the possibilities for temporary storage of industrial effluents are virtually nil. But even in the most favorable conditions where underground caverns and solution holes exist on a large scale above the water table, the caverns cannot be thought of as permanent underground storage. Material emptied into such openings will surely find an escape into some surface stream, although it may be miles away. Consequently, the utilization of underground cavities for waste disposal must be limited to those instances where the cavernous conditions give good

Nature and extent also character of crevices, open to grade, relation and structure and underground drainage. WMM

OK where depth, geologic structure, character and kind of bedrock are favorable. WHM

possibilities for precipitation or settling out of the contaminants in the effluent before the disposed solutions find their way into surface water courses. Effluents bearing suspended aluminous silicates, calcium hydroxide, or slightly acid solutions would be suitable for consideration for underground disposal under ideal geological conditions, but chemical solutions high in chloride can be expected to retain their contaminants in solution and to improve in chemical character in underground travel only to the extent that they become diluted with ground water.

Thus even under the most favorable geological conditions——conditions which do not prevail in the vicinity of Saltville——underground disposal of chloride solutions ought not to be considered as feasible. There is too great a risk of wholesale contamination of a large supply of ground water with chloride-bearing effluents to permit any experimentation with underground disposal of the industrial wastes from the Saltville Plant.

Experts in the field of ground water, such as Mr. Sayre, of the United States Geological Survey, are generally agreed that underground disposal without unsatisfactory results is possible only under special, localized conditions. The general policy of the United States Geological Survey is to recommend against underground disposal of wastes, but at the same time the Survey geologists recognize that there are situations which make such disposal feasible and necessary (Personal communication from A. N. Sayre, February 9, 1953).

All of the available evidence pertaining to the Saltville area points to the inadvisability of attempting underground disposal of effluents from the Saltville Plant. The only possible porous stratum which occurs at depths of about 4,600 feet probably contains water under hydrostatic head and thus would in all probability refuse water from higher levels or from the surface. All the evidence obtained from deep drilling in southwestern Virginia, including all known drill-hole data, indicates that fractures in the deeply buried beds have been completely closed with secondary mineral matter. In view of these situations, it must be concluded that deep disposal is not a significant possibility.

Respectfully submitted,

Byron N. Cooper

Submitted in Triplicate
February 14, 1953