with axle-boxes outside of the frames. Their plates are 1 1-16 inches thick. The truck is of the direct-traversing type, held flexibly to center by a double elliptical spring. The pivot is a steel casting of large size, the neck of the pivot being hollow, 7½ inches diameter, and the weight being carried on a flange 2 feet diameter, stepped into a deep collar-bearing, also of steel castings, lined with bronze. The pivot is held to its seating by a central pin 8 inches long and 2⅜ inches diameter.

To prevent any chance of binding or strain the pivot neck is rounded slightly, as the outer edges of the engine frame have no rigid supports, coiled springs being used instead for the lateral steadying of the main frame. A feature to note also is the spherical ends of the camber pins of the bogie springs, stepped into corresponding holes in the axle-box crowns.

An exceptional arrangement exists in the double or trussed equalizing levers of the driving springs and by which the weight is carried between the two plates on a pair of knife-edged supports in place of the usual fulcrum pin. The bracket by which the frame is supported projects downward from the latter and passes between the trussed plates of the equalizing beam.

The cab fittings are of the simplest possible form, and very few in number. The regulator handle has an unusual disposition, it being jointed in two parts so that the engineman can work it from either side of the footplate. The two parts mesh together by means of toothed quadrants, and a latch in the handle locks the two halves of the lever at any angle of adjustment. There are two injectors, Friedmann's No. 9, and the brake is the Westinghouse.

A good deal of space is available in the cab, which is exceptionally wide, and provided with the deep front windows so convenient in American cabs. A door gives access to the running board on the fireman's side, and the whole of the footplating is provided with the regulation Russian guard railings. Gutters and spoutings are fitted to the cab roof.

The tender carries 5 tons of coal, and 14 cubic meters, or 14 tons, of water. It runs on six wheels, of 3 feet 7¼ inches diameter, having a total base of 27 feet 11 inches. Equalizing beams connect the ends of the two pairs of forward axle springs. All springs have spherical ends to the camber thrust pins where they rest upon the axle-box crowns. An elliptical spring is used for the buffing and draught arrangement at the front of the tender, and a volute spring is employed for the draft hook of the front buffer beam of the engine. Rubber ball cushions are provided on the safety chain hooks. The tender is exceptionally wide—9 feet 10 inches—and a lining of wood is interposed between the tank and framings upon which it rests. The height of the water is indicated by a float connected to an index hand. The following list completes the general dimensions:

Cylinders (four)—	
High-pressure, diameter	0.365 m.
Low-pressure "	0.547 m.
Piston stroke	0.610 m.
Wheels—	
Coupled, diameter	2.000 m.
Bogie "	1.000 m.
Journals of driving axles	.195 mm. dia. × .260 mm. long.
" bogie "	.175 mm. dia. × .300 mm. long.
Tractive effort, maximum	6525 kilogs. = 14,355 lbs.
Boiler—	
Heating surfaces, exterior, of firebox	13.68 square meters.
Heating surface, of tubes	132.40 "
Total	146.08 "
Grate area	2.615 "
Boiler pressure	13 atm.
Capacity of boiler for water—10 cm. above fire-box crown	4.65 cubic meters.
Capacity of boiler for steam—total	2.48 "
Volume of the two domes	0.808 "
Height of boiler center from rails	2.500 m. = 8 ft. 2⅜ in.
Areas and ratios—	
A, area of air passages in grate	0.930 square meters.
B, " " tubes	0.344 "
Ratio of A to B	2.7
Ratio of total heating surfaces to grate area	55.8
Ratio of tubes heating surface to that of fire-box	9.68
Frames, inside—	
Width apart	1.290 m.
Length	10.264 m = 33 ft. 8 in.
Thickness of plates	.030 m.
Weight—	
Engine, empty	51.5 tonnes.
" loaded	56.5 "
On each bogie axle	13.25 "
" driving axle	15.00 "
Tender, empty	16.00 "
" loaded	35.00 "
Engine and tender, loaded	91.50 "

—Engineer.

SOME ENGINEERING FEATURES OF DRAINAGE.*

By C. G. ELLIOTT, Drainage Expert, Office of Experimental Stations.

INTRODUCTION.

WHATEVER may be said regarding the value of drainage in its various relations to industrial progress, its most far-reaching and lasting benefits arise from purely agricultural sources. It has been the means of greatly increasing the productive capacity of large areas and contributing to the comforts of country life.

Those who are unacquainted with the principles and practice of drainage for agricultural purposes have but to compare the unproductive swales, overflowed river bottoms, and limitless swamps which may be found in partially developed sections of our country with some of the most productive farm lands and prosperous communities of this and other countries, to understand in some measure the magnitude of the results which have been brought about by the practice of drainage. The engineering and legal difficulties which have been surmounted in the accomplishment of these results have enlisted the services of prominent statesmen as well as able engineers. In recent years the subject has attracted the attention of discerning business and professional talent to such an extent that the intelligent development of lands by methods known to the engineers is becoming better understood and more widely practised.

The occasion for increased interest in this subject becomes more pronounced each succeeding year. In the opening up of a country it is natural that cultivators should first seek out and appropriate those lands which, by reason of their location and natural condition, are best suited for productive purposes, and can be cultivated with the least possible outlay of labor and capital. The neglect of waste lands, whatever their condition or area, occasions but little concern as long as there is a sufficient acreage of easily accessible arable land to occupy the attention of the agricultural people. With the increase of population and a corresponding added demand for food products, the reclamation of waste lands by drainage in such a manner as to fit them for the production of valuable crops, and the improvement of those already cultivated for the purpose of adding to their productive capacity, have assumed an important place in both agricultural and commercial activities.

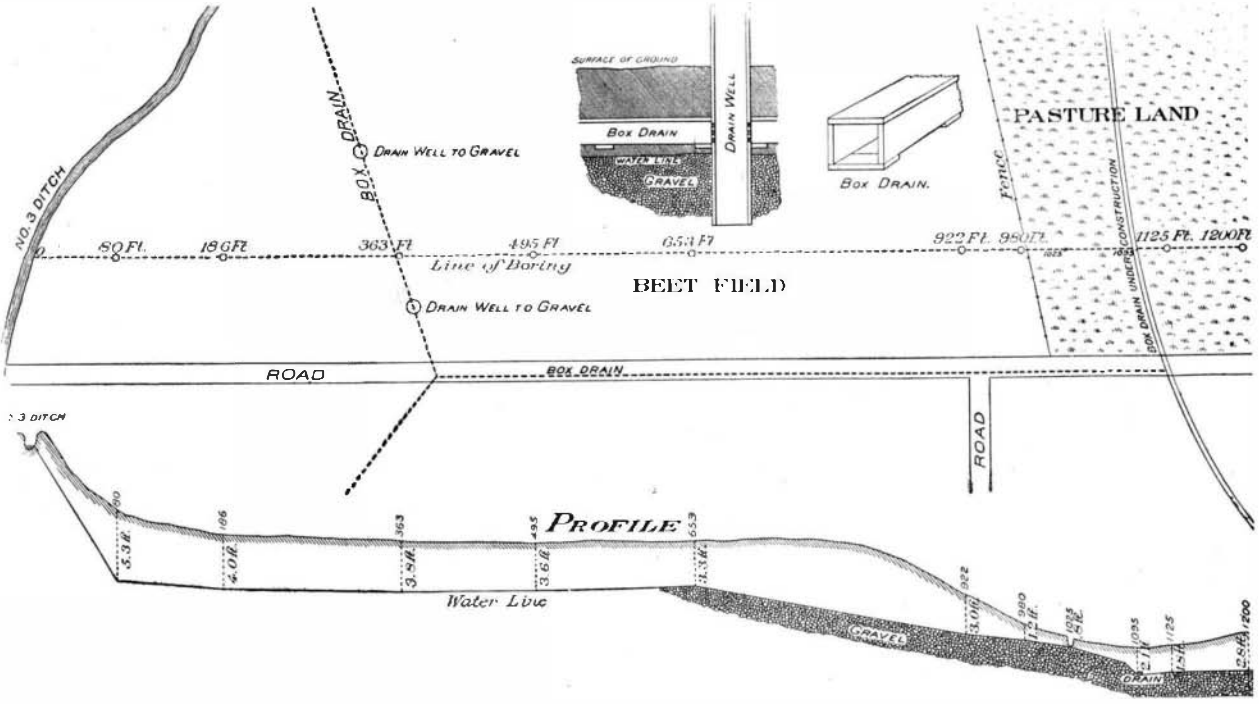

FIG. 1.—PLAN FOR DRAINING FIELD NEAR GREELEY, COL.

Not only is the reclamation of land required in humid regions, where it has been supposed that the art of land drainage is alone applicable, but irrigated areas in the West furnish many instances which emphasize the need of drainage for lands which have been reclaimed by the artificial application of water. In fact, it may be said with truth that all lands require drainage, either by natural or artificial means, if they are to be relied upon to yield their best fruits to cultivators. A proper regulation of the quantity of soil water is necessary, be it furnished by rainfall direct upon the surface or by methods used in irrigation. The problem which confronts the engineer contains three important considerations which he should take into account: (1) The quantity of water which should be removed from the soil; (2) the plans and methods to be employed in accomplishing it; and, (3) provision for the proper disposal of the water removed.

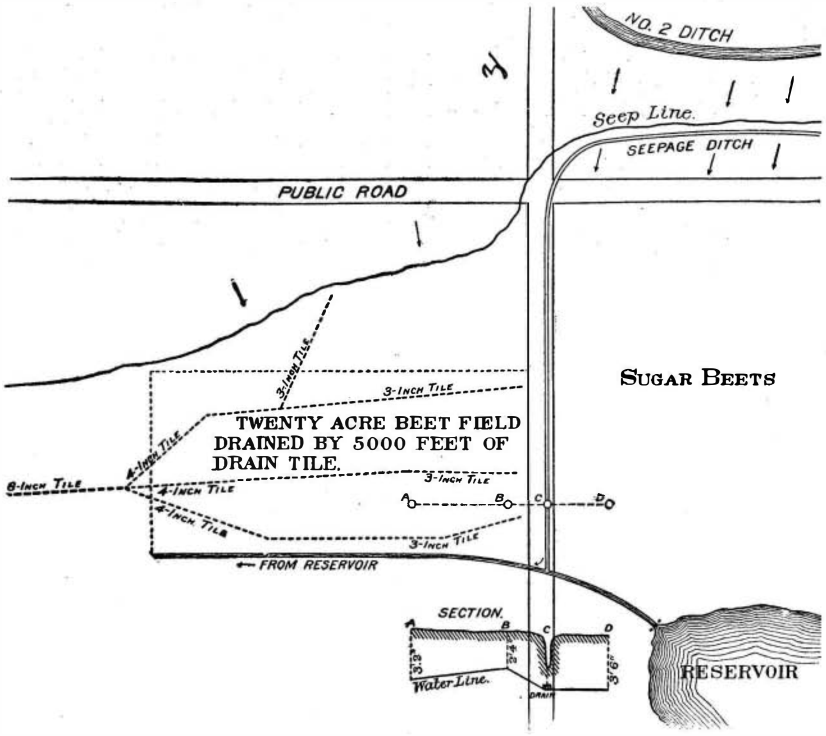

FIG. 2.—DRAINS AND SYSTEMS OF LOCATION ON FARMS NORTHWEST OF GREELEY, COL.

DRAINAGE OF RAINFALL.

With reference to the division of this subject most commonly recognized—that is, the drainage of lands receiving their water from rainfall—it may be said that the quantity to be removed is subject to several modifying contingencies for which due allowance, as far as practicable, should be made. This phase of the subject, when discussed in works on drainage, is often dismissed with a mere reference to the average rainfall of the locality and a few remarks upon the value of such data in planning an efficient drainage system.

It is not the average rainfall with which we are concerned in land drainage, but the maximum precipitation at various times during the growing season. This should be considered in connection with conditions of soil and weather at such times. It is not infrequently the case that after a season of drought a rainfall of 2 inches of depth in twenty-four hours may be fully absorbed by the soil, while at other times and under different conditions a large part of a like precipitation must be provided for by either surface or underdrainage or a combination of the two.

SURFACE STORAGE.

The storage capacity of the surface of the land which may be used without detriment to its productive value occupies an important part in the plans for drainage, especially where large tracts are under consideration. The percentage of slope of an area toward its natural drainage courses and the obstructions which retard the surface flow of rainfall present engineering problems of a local nature. For example, where the tract is large and nearly level, the movement of water by both natural and artificial drainage is slow, and a larger percentage of rainfall is evaporated, stored in the soil, and used by the plants in a given time than where the slopes are sufficiently great to make the run-off rapid, thereby overcharging main drainage channels for a short time and carrying off water which it would be better to have pass over or though the soil more slowly. For this reason the drainage of level areas of large extent can be accomplished with smaller main channels, considering their carrying capacity, than that of more undulating land with irregular and varying contour. It may be further said that the results arising from such drainage are more salutary, and have attracted wider attention than in the latter case.

As an example, it may be assumed that the main drainage of a tract of large extent and level contour may be provided for by a channel computed to carry one-half inch of water in depth from the entire area from which it receives drainage in twenty-four hours when the channel runs eight-tenths full, two-tenths of the full carrying depth being reserved for contingencies not entering into computations for channel capacity. The methods of draining the interior of the tract, and the subsequent uses to be made of the land, have a modifying effect upon the work which the main drainage will be called upon to perform. If done by systems of underdrains, with supplementary open-

---

* From Year Book of Department of Agriculture.

ditch laterals, the time taken for the removal of water will be extended several days, thereby making the maximum discharge required of the main channel sometimes 10 per cent less than where the entire work is accomplished by surface drains alone.

The considerations which will apply to land just described, with reasonable accuracy, will be far different for a tract of rolling or broken land interspersed with level areas. Here, again, the degree of slope and the changing character of the soil and surface conditions present a variety of important features for the attention of the engineer. The maximum quantity of drainage to be provided for in twenty-four hours may be one inch of depth, or even more, for the entire watershed, with many complex questions of interior drainage to look after. The aim should be in such cases to hold back and distribute the water from the more elevated lands rather than to concentrate it; to provide for its entrance into and passage through the soil rather than over it; to store a portion of it in the lower strata of the soil instead of hurrying it into the main drainage by the most direct course possible. At the same time, the level portions must be protected and drained in accordance with the requirements of their peculiar situation. A due regard to these considerations in the planning of drainage works for lands, such as just described, will retard the surface wash, prevent waste of soil from rolling lands which adjoin level flats, and conserve moisture needed for the higher lands, while, at the same time, it will assist in taking care of the drainage of contiguous low-lying or valley lands and arrest the distribution of rainfall through the soil by artificial drainage as well as by surface control. This is an important engineering feature of drainage which merits more attention than it has heretofore received. While the quantity of water to be removed from soil and the plans for accomplishing it are analytically different subjects, it is not difficult to understand, from what has already been said, that in practice they are intimately connected. The quantity of water to be provided for in a given time will have much to do with the design of plans and methods of accomplishing the drainage of lands.

The details of this work involve the consideration of numerous local conditions. While the general principles are the same, the surveys, computations, and plans for the accomplishment of efficient and economical work in any particular locality should be evolved in accordance with the conditions and surroundings peculiar to it. The engineer's treatment of the case must be largely influenced by precedents and former practice under analogous conditions. In this regard, however, drainage engineering is not unlike other divisions of practical work directed by scientific methods, but investigations along this line have not been as persistently and carefully pursued as those for other divisions of hydraulic work.

DRAINAGE OF IRRIGATED LANDS.

While the drainage of humid lands has been practised for years and its utility is well established, its importance in the cultivation of irrigated lands has only recently forced itself upon the attention of owners. The necessity for drainage here, however, arises from causes so different from those which prevail in humid areas, and the conditions of soil, methods of cultivation, and weather are so different that a description of them will be necessary to a proper understanding of the situation. Strange as it may seem, there are some areas now requiring drainage which were once almost destitute of soil moisture.

The water which has converted the desert into the productive farm is derived from streams supplied by the melting snows of the mountains. Portions of these streams are diverted at various convenient points after they leave the mountains and the desired quantity of water conducted for miles, by means of ditches, to those lands which it is destined to irrigate.

Laterals are taken out at favorable points and the water used upon lands until the last diminutive stream vanishes in the greedy sands of an unwatered plain. These ditches pass across the slopes and around the hills in such a way as to maintain the light grade necessary, and upon elevations sufficient to give water service to a large acreage of lower lands. The soil through which they are constructed often contains large quantities of gravel and sand, or, in some cases, laminated shale, making it the most unsuitable material possible through which to form a water conduit. In some cases they pass through gypsum formations, which material, besides having a remarkable affinity for water, permits excessive leakage by reason of the loose structure which is usually a characteristic of such beds. When first constructed it requires some time to get water through the entire length of the ditches, and not a little expense is necessary to repair injuries done to them by washouts and the settling of bottoms, which take place during the early history of every canal. While these losses diminish greatly after the banks of the canals have become settled and the crevices closed by silt, the loss of water is never effectively checked where the canals pass through loose earth, but continue to add to the underground waters of the plain. This loss has been detected by comparisons of measurements of the quantity of water taken out of the stream with those representing the sum total of water distributed. This is called "loss by seepage," and varies from 15 to 95 per cent of the entire volume diverted from the stream. The waste finally reaches, at some lower point, the stream from which it was originally diverted, and is classified as "return waters."

Could the ditches pass through earth practically impervious to water, or could they be lined with some preparation to make them water-tight, the conditions which prevail on the lower lands would be far different, but owing to the great size and length of many of these canals, the difficulties and expense attending this process are such as to be practically prohibitory. The losses by leakage in most instances are accepted as contingents of irrigation systems. The elevated position of the water carried by the supply ditches furnishes a constant pressure head to every stream of water, however small, which finds its way through the bottom of the channel. To this head and to the permeability of the earth may be attributed the presence and dissemination of seepage water, which, in time, manifests itself upon lands which have been irrigated and successfully cultivated for a term of years.

The soils in most irrigated regions are deep and loose, containing a small percentage of clay, but rich in concentrated plant food. They are finely divided and possess great capillary attraction for moisture; and, moreover, their physical structure is such that they are most easily kept in perfect condition by judicious cultivation. Further than this, they permit a ready passage of water through them after capillary spaces have been filled. The rainfall is so far deficient that water must be obtained from supplies diverted from mountain-fed streams and brought and distributed by ditches. The effect of this application of water to soils under judicious management is remarkable, as the abundant and valuable products obtained from such lands attest. The irrigator applies water by surface flooding, using such quantities as his judgment and experience may dictate, feeling sure that any excess which he applies will speedily pass to the lower soil, which, under primitive conditions, being dry to a depth of from 40 to 60 feet, porous and open, affords unlimited drainage facilities. The large amount of leakage from the main canals for a time finds a ready and harmless exit into the lower soil. Under such conditions the under strata become a regulating reservoir, which receives by percolation the leakage from irrigation canals and drainage from over-irrigation, thus securing to the cultivator as perfect soil conditions as can be desired.

FILLING UP OF THE SOIL WITH WATER.

Under such conditions it will be only a matter of time when the lower soil will become filled with water and this will rise until the saturation extends to the surface, similar to that with which we are familiar in humid climates. These conditions already exist in all of the older irrigated lands in such a degree as to call emphatic attention to the injury done and to cause no little concern regarding the proper treatment of the lands which have become saturated. That the injury to lands from this cause is increasing rather than diminishing and that some plan for their drainage should be made and put in operation are conclusions reached by careful observers of the changes going on in irrigated districts.

THE PROCESS OF SEEPAGE.

A few general facts observed in California and Colorado may be valuable to those who are unfamiliar with this new drainage question. As would be expected, soil water usually first appears on the surface of the lower levels of land, being brought there by percolation through the soil from some more elevated supply, which forces water through the soil more rapidly than its natural drainage facilities will remove it. In other instances it appears not far from a supply ditch, the underflow having apparently been arrested in its passage through the soil by some less pervious material which has caused the water to rise to the surface instead of continuing its course through the soil at sufficient depth to be harmless to vegetation, until it finally reaches some drainage stream. In the areas which are nearly level the appearance of the surface water is more general, the quantity depending much upon the texture and condition of the lower soil. The saturation of irrigated land by seepage from supply ditches and from over-irrigation will alone destroy their productive value as effectually as surplus water is known to destroy the productivity of lands which are overcharged with rainfall.

ALKALI CONDITIONS OCCASIONED BY LACK OF DRAINAGE.

There is an additional menace, however, accompanying the saturation of these soils which is peculiar to them and which in many instances manifests itself before the water appears at the surface or is at all troublesome to cultivators. Many of these soils contain considerable quantities of sodium chlorid, sodium sulphate, and sodium carbonate, which originate in the rocks from which the soils are formed and are distributed through them, forming an essential part of their fertility under normal conditions. Lands which up to a certain time have produced crops in quantity and quality to which no exception can be taken may, without apparent cause, begin to deteriorate and continue to do so. Upon examination, it will be found that the alkali salts have accumulated near the surface in such strength as to destroy crops which had previously been successfully grown. Upon further investigation as to the cause, it is found that the abundance of water in the lower soil has dissolved large quantities of alkali and holds it in solution. The rise of water to a plane at or near the surface from which rapid evaporation takes place results in a deposit in solid form of all alkali contained in the water evaporated. The active capillary power of the more finely divided soils accelerates the upward movement of the water, the evaporation of which is rapid in the arid climates, resulting in a deposit which constantly increases from year to year. The first stage of this evil is but the forerunner of the more serious results which follow in the train of oversaturation of irrigated soils, which must be witnessed in order to be fully appreciated. These general conditions are not uncommon to all of the older irrigated districts. The value of drainage to such lands for the purpose of restoring them to their former productiveness, as well as to arrest the progress of the evil when once detected, is sufficiently demonstrated to merit investigation by all cultivators of irrigated soil. In fact, drainage is the only efficient method known for removing alkali.

SOURCE AND MOVEMENT OF WATER TO BE REMOVED.

In the drainage of seeped land under irrigation there are a few fundamental questions which should be considered, the first of which is the source of the water to be removed. The prodigal use of water during the first years of the cultivation of the land under new ditches, together with the enormous losses of water incident to new construction, have contributed largely to produce the water-logged conditions now found in the lower soil. From the history of early irrigation in the Fresno district in California, it appears that a vertical depth of 5 feet of water was occasionally applied in a single irrigation, and the depth applied during a season would sometimes be equivalent to a total of 20 feet. Such extravagant use of water does not often prevail in the older irrigated regions, so that the water requiring attention in drainage is now for the most part derived from the seepage of supply ditches. It comes from the subsoil, and is subject to a constant gravity head furnished by water in the supply ditches, which always occupy a higher level than the surface of the land irrigated. The supply is constant during the growing season instead of intermittent and occasional, as is the case of water from rainfall. The soil is of an open character, and permits the ready passage of water through it. It also has high capillary power and carries water to the surface with remarkable freedom and persistency, much more so than soils containing a large percentage of clay or coarse sand and gravel; hence the depth of drainage is an essential feature of its success, for the reason that soil water should be kept so low that capillary water will be appropriated by the soil and plants before it reaches the surface. This should rarely be less than 4 feet, and greater depth is frequently more efficient. A proper location of drains, both as to depth and position, is of first importance. After the source and movement of water have been ascertained, a single drain may frequently be so located as to intercept and conduct away water which might otherwise destroy the value of hundreds of acres of land. The reclamation of the tracts already seriously injured may be accomplished by the same well-directed measures. There are a sufficient number of instances of successful works of this kind in California and Colorado to establish its efficiency under wise administration. It may be added, also, that the failure of shallow drains and ill-directed location emphasizes the wisdom of careful investigations upon these points.

PRACTICAL DIFFICULTIES IN CONSTRUCTION OF DRAINS.

The practical difficulties of drainage construction in these soils are in some respects quite formidable. The earth is easily and cheaply worked when dry, but difficult and expensive to handle when wet, unless a bed of gravel is encountered; gravel prevents the slumping of the fine soil which, under saturation, becomes semifluid in consistency.

It is a fortunate characteristic of irrigated lands that the plane of saturation begins to lower as soon as the supply of water is turned out of the ditches, so that between that time and the beginning of the following irrigating season, ditches for either open or covered drains may be constructed not only with reasonable dispatch, but with an assurance of being in perfect condition when completed. The wisdom of carrying on construction work when soil water is at its lowest stage is apparent to all who have attempted such work in the deep and open soils of irrigated districts.

DISPOSAL OF WATER.

The disposal and use of drainage water derived from seeped lands is a matter of peculiar interest to irrigated regions, because of the value attached to the water as an irrigation supply. Its use, so far as ascertained, is wholesome and may be made without fear of any injurious result from alkali. It may be diverted from the drainage ditch or collected in reservoirs and thence distributed by the usual methods, thus adding to the available supply of water for that locality. Such water has a value, in many localities a high value, and as drainage becomes better understood and more widely practised the water will constitute an important commodity among land owners. In some localities in Colorado it is being developed by drainage works at private expense and appropriated as an additional irrigation supply. Over 400 filings on seepage and drainage streams have been made in Colorado in the South Platte Valley alone, and proceedings at law in that State have affirmed the right of appropriators of such water to its use as against any subsequent appropriation which will divert or interfere with the flow of drainage or seepage streams already filed upon. The development of water by drainage works brings into prominence new legal phases of the water question, which have not thus far been made subjects of legislation, but which should receive early investigation and attention.

KINDS OF DRAINS.

The theory of drainage may appeal with much force to the landowner, and he may have great confidence in the results of the work when carried out, but the matter will receive only a passing notice unless its practice is shown to be feasible and remunerative. This is a feature of the work which commands immediate attention. The different conditions existing between regions where rainfall is a direct source of soil water and where seepage from reservoirs and canals furnish it through underflow suggest a difference in the plans, but not necessarily in the kind of drains which may be used. Open ditches, by reason of the depth at which they should be maintained and the unstable character of the soil, entail a constant expense for cleaning, which is unavoidable. Where the ditches are seldom flushed, their filling by sand, vegetable growth, and surface rubbish carried by winds occasions a necessity for at least one annual cleaning. Box drains are in favor in Colorado, where the quantity of water to be carried does not require a drain of large capacity. The advantages claimed for them are that they are cheaply made and may be secured in place in wet soils with greater ease and certainty than earthen draintile and sewer pipe, which must be laid in short sections. They are used with success where field crops are grown. When constructed with no bottoms, as is common with those of small capacity, their usefulness is limited to low grades; otherwise underwashing will destroy the usefulness of the drain by throwing it out of position. The lasting properties of the lumber used for this purpose will be measured by the degree of continual saturation to which it is subjected. The drains used should be lasting as well as efficient. In Fig. 1 is shown the manner of draining a field of seeped land near Greeley, Col., which was made unfit for cultivation by leakage from the supply canal adjoining. The drains are of the box pattern and laid about 4 feet deep. The diagram shows a profile of the water line, as determined by borings made in August, 1902. There appear to be beds of gravel underlying this land in some localities. Where these beds could be located, small curbed wells 10 inches in diameter were sunk into the gravel and the drains connected with the wells. It is claimed with good reason that these wells relieve the hydrostatic pressure of the free water in the gravel, the water rising in them and passing off through the drains instead of being forced upward through the soil. The thrifty crop of sugar beets growing on this land the first season after drainage was evidence of the success of the work. At the time these examinations were made a larger and more extended drain was being constructed in an adjoining field occupying a lower level. The profile of the water-line shows the need of an additional drain, which will be laid approximately parallel with the supply canal.

Stoneware draintile constitutes an ideal material for underdrains. Owing to the practice of constructing such drains when the soil is saturated with water, there has been some difficulty experienced, in Colorado at least, in placing and maintaining the tile in position and also in keeping them free from sand. Their excellence as a water conduit and their durability are unquestioned. Their cost, however, being much greater than lumber, stands in the way of their adoption in localities which are distant from manufactories.

OPERATION AND LOCATION OF DRAINS.

Notwithstanding their expense, draintile are used with success, to a limited extent, in the fruit lands about Fresno, Cal. A provision for keeping the lines free from small roots, which constantly seek the flowing water, and would soon fill the drains, is found necessary. This is accomplished by passing cylindrical wire brushes through the drains every few months. Manholes, for the purpose of obtaining access to the drains for this purpose, are maintained at distances of 400 or 500 feet along the lines. Where these soils are chiefly occupied by trees and vines the drains must be scoured periodically by some process similar to the above, which will constitute an expense for maintenance peculiar to such localities. For this reason, and also because the grades are light, perfect work in the construction of drains must be secured.

The objection is urged that some kinds of drains are not effective; that water fails to enter them in sufficient quantity to accomplish the desired work; that, notwithstanding their presence, the land they are intended to benefit remains undrained. It is true that there are many instances which apparently support this conclusion. The writer has witnessed cases where underdrains were discharging water in continuous streams, yet the soil directly over them was saturated. In other instances the soil in close proximity to the drain was dry and productive, while 15 feet distant it was producing only water grasses. Open drains are liable to the same objections. The failure of the drains in the cases referred to was owing not to the material of which they were made, but to their faulty location, either in surface position or depth or both. Proper surface position and proper depth are essential factors in the successful drainage of seeped lands. Since the source of water is underground, its course must be found and the drains so located as to intercept its flow in the most effective way. This constitutes one of the arts bearing directly upon the successful drainage of irrigated lands.

It is, however, sometimes no easy task to locate drains properly. In this connection it is interesting to note that no greater impetus was given to the practice of drainage in England than at the time that Joseph Elkington, a Warwick County farmer, unlettered and ignorant, became so proficient in locating surface water and in arresting its course and leading it away that he became famous in neighboring counties as well as his own in draining soil which had hitherto baffled expert engineers. In recognition of his great service to agriculture, Parliament, in 1795, voted him the sum of £1,000 sterling. The Royal Agricultural Society previous to that time commissioned one of its members to collect and publish such information as could be obtained from Mr. Elkington in order that his art might be made available to the people. The same importance should be attached to the location of underground water in irrigated lands. A failure in this particular is largely accountable for the charge sometimes made that water does not enter the drains. The writer calls to mind a field on a farm north of Longmont, Col., that has been drained thoroughly with the exception of one portion of about 2 acres, which, notwithstanding the presence of drains around and through it, remains a swamp. The source of supply has not been found.

While upon this most practical subject pertaining to drainage, reference may be made to Fig. 2, in which are well represented two kinds of drains, as well as two systems of location, which are found in adjoining fields on farms northwest of Greeley, Col. In the one, a system of tile drains has been laid about 4 feet deep through the land immediately affected by seep water; in the other, an intercepting ditch has been made for the purpose of cutting off the water from the ditch before it does injury to the field. Each plan apparently accomplishes the work intended. The tile drains furnish a continual stream and the growing beets on both fields show equal thriftiness. There is a difference, however, in the cost of the two, and borings show that the water line is lower in the land drained by the single cut-off ditch than in the field where tile drains have been used.

FIELD ENGINEERING.

The location of drains should be made when the ground is wet, so that the outcropping water, its effects, and the course of its underflow can be ascertained by suitable test borings. After this has been done, advantage should be taken of the fact that the level of soil water recedes between the irrigating seasons and sinks so low that drains may be constructed in dry ground. The lines should be surveyed, the grade located, and the drain, of whatever kind used, constructed in accordance with the survey. The risk and expense arising from caving ditches, running sand, and all of the contingencies incident to such work would in this way be largely avoided and the drains completed under the best possible conditions. Here is a field for the investigation of the minimum grades which may be permitted under the several conditions to be considered and the best methods of disposal of the water, together with size of drains and specifications of their construction.

THE NEW DRAINAGE FIELD.

There is no question but that there is ample room for profitable investigation in this new drainage field. The irrigation of the arid lands of the West has developed a necessity for drainage which is destined to follow in the wake of the reclamation of all desert land. Owners of such lands should be early apprised of this menace to their property. Care in the application of water and watchfulness for the first indications of saturation or appearance of alkali, with proper preventive measures, will go far toward arresting this growing evil in newly developed districts. It is well proved that alkali in cultivated lands is the result of oversaturation, arising principally from the seepage from ditches. It seems equally well assured that if the water line of the soil can be reduced by drainage to within 5 feet or more of the surface, the accumulation of alkali to an injurious degree will be prevented.

Sufficient work has been done in Colorado to demonstrate that judicious drainage will reclaim lands already saturated, that it will prevent the rise of alkali, and that land which has become water-logged and injured by alkali may by this means be restored to its former productiveness. The success of this promises to be as marked as that of drainage in well-watered States of the East and Middle West. Since the time underdrainage was introduced in New York, in 1836, its value in reclaiming, restoring, and developing the soils of the country has been incalculable. The work still goes on as a well-tried and standard method of increasing the productiveness of the soil. Drainage in the irrigated districts promises equally important results, and will be more universally practised as the lands grow older. When lands have once been proved to be profitable under irrigation it is poor policy to permit them to be ruined by the same agency which has developed their productiveness. Among the numerous instances of injury to lands from this cause, which may be found in different States, there are doubtless a great variety of conditions to be met and many unsolved problems relating to their reclamation, yet some application of the well-established principles of land drainage will be of utmost service. This problem has been considered as applying only to those lands which have been proved by actual cultivation to be of the highest productive value under ordinary irrigation practice. They have not been depleted in fertility, and for that reason abandoned, as is the case with long-cultivated lands in the East. Their value is not impaired for lack of market for their products. On the contrary, they are fertile in every desirable particular, and are capable of producing crops of superior quality, which are sought for in the markets. The lands requiring drainage are often the choicest, so far as location is concerned, and more desirable than new and unimproved areas. The suggestions regarding their restoration to the realm of profitable irrigated lands have been deduced from somewhat limited investigations, and their application to lands in similar conditions in other States may be subject to revision. The subject is certainly one of such importance as to merit a full examination in every district where the conditions herein described prevail.

THE PASSING OF THE ENGLISH SPARROW.*

By HAROLD BOLCE.

THROUGH comprehensive investigation conducted by economic ornithologists, the important discovery has been made that the English sparrow has passed its maximum limit of abundance in the United States, and is now diminishing in numbers. As is well known, a large part of the civilized world long since joined in a vendetta against this objectionable bird. But the English sparrow avoided traps, shunned or survived poison, evaded hunters, and overran the earth.

Now several species of hawks and owls are accomplishing what was impossible to man. Among the most active in the sparrow warfare in the United States is the little screech owl (*Magascops asio*), and in Canada the little saw-whet or Acadian owl (*Nyctala acadica*)—birds not much bigger than the prey they are slaughtering. The number of English sparrows consumed at the banquets of their raptorial enemies is enormous.

Simultaneously with the discovery of the beneficial activities of owls and hawks in checking the dominion of this hitherto conquering bird comes the unique announcement from a medical scientist in the United States army that a species of mosquito is spreading malaria among the great flocks of English sparrows. Officers of the British army medical corps have also made the discovery that a malarial germ, transmitted by mosquitoes, has attacked the English sparrow. It is not probable that the malarial parasite in itself would be sufficiently powerful to decimate the species, but incidentally as a co-worker with the rapacious birds that have combined to conquer the sparrow pest in America, the mosquito assumes new and unique interest. *Proteosoma grassi, hæmaneoba relicta* is the name given to the malarial organism which has begun to devitalize the blood of the English sparrows. The mosquito waging warfare on the birds is a species of *Culex,* which, so far as is known, is not a conveyer of disease to man in temperate zones. Its method of transmitting malaria to sparrows is similar to that employed by the genus *Anopheles* in inoculating human beings with the germ. The discovery that malaria has attacked the English sparrow has come about through experiments in permitting mosquitoes that were known to have fed on men and animals suffering from malaria and other maladies to attack live birds. It was believed that without the jeopardy to human life which is involved when experiments are made upon men, important tests could be conducted demonstrating the power of mosquitoes to transmit many diseases, besides malaria and yellow fever. These experiments are still being carried on, and incidentally it has been learned that, without laboratory encouragement, mosquitoes have been diligently at work spreading malarial contagion among the millions of English sparrows in many sections of America. The bird and insect conspiracy against the English sparrow is extensive and formidable. The unremitting slaughter by hawks and owls is visibly thinning the vast army of these birds.

At the time of the introduction of *Passer domesticus*, as the English sparrow is known scientifically, it was believed by many people that it would rid America of many kinds of insects. Experience, however, proved that this bird protected dangerous insects by driving out other birds that had kept them in check. For example, the orgyia caterpillar (*Orgyia leucostigma*), very injurious to shade trees, is a formidable diet, which most birds, including the English sparrow, carefully shun. This noctuid has an armament of bristling hairs which renders it unpalatable to the great majority of insectivorous birds. Furthermore, the robin, the Baltimore oriole, the black-billed cuckoo, and the yellow-billed cuckoo are exceptions to the rule and seem to be charged with the special mission of ridding the earth of these and other hairy caterpillars. It was not only in driving off these four species of birds that the English sparrow gave protection to this particular pest. It was discovered that to some extent the English sparrow, while not insectivorous, did destroy some insects, but in so doing it chose less harmful and more appetizing species, and so, reducing the struggle for existence in the insect world, gave a freer field for such noxious kind as the orgyia, or white-marked tussock-moth, as it is popularly called. That is simply an illustration of one phase of the English sparrow's evil reign. The indictments against the bird, as is well known, are legion. Now with the decrease of the sparrow is noted a corresponding diminution of the destructive insects, for the insectivorous birds once banished are returning. The black and purple martins are coming back in flocks. The "Robin Redbreast" this year reappeared in city parks that for years have been surrendered to the sparrow. Wrens, mocking-birds, swallows, song and chipping sparrows, Baltimore and orchard orioles, phœbe birds, warblers, and yellow-birds are among the joyous company flocking in to resume their minstrelsy in their native parks and fields.

It is confidently believed by economic ornithologists that the whole country will before long feel the beneficial effect of the downfall of the English sparrow. To that end, protection is urged on behalf of the hawks, the butcher bird, the owls, and other species that are performing valiant labors in the interest of American agriculture.

At first English sparrows confined themselves almost exclusively to cities and towns. Gradually, as towns and cities became overrun, the sparrows extended their range into the country. Sometimes when they utilized side-tracked box cars as convenient roosts, they were carried into new environments, but speedily made themselves at home, inaugurating at once a systematic and pitiless warfare upon the insectivorous and song birds of the neighborhood. Farmers who had not seriously regarded the hostility of city people toward sparrows soon realized the secret of that feeling. In some localities orchard and field crops have been almost totally devoured. The grapes and berries consumed by the ravenous sparrows aggregate thousands of tons annually. In every point in the development of all kinds of crops, from seed-time to harvest, the sparrows became a pest. The branching out in the country has been an important factor in the sparrows' downfall, for it raised up against them the enemies now hounding them to destruction. From their strongholds in the cavities in cliffs and their hiding places in ancient trees, birds of prey fared forth to dispute sovereignty with the invaders. In winter time when food is scarce, the sparrows flock back to the city and thither the raptores have followed them.

It was the shrewd sparrow that first learned that in cities it enjoyed immunity from hunters, but now the hawk has discovered that it, too, may safely venture within municipal lines. The great northern shrike, or butcher bird (*Lanius borealis*), has likewise returned to its attack upon sparrows, and is a powerful ally of the hawks, for it has great powers of mimicry, and has discovered that by imitating the distress call of the sparrow it can summon a flock about it. Thus decoyed, these birds fall easy victims to their lurking enemies. The shrike was a pioneer in the anti-sparrow movement, but like many other forerunners of a great cause it suffered martyrdom. In one large American city, the municipal authorities employed men whose sole duty was to slaughter shrikes, for the belief then was that the sparrow was a blessing to the country and that no enemy should be permitted to wage warfare upon it. In some parts of the United States the bluejay levies upon the eggs and nestlings of the sparrows, and the crow-blackbird or purple grackle has entered the list of adversaries of the alien bird which now all day long, from one end of the year to the other, is beset by powerful foes. At night when hawk and shrike and purple grackle cease from troubling, the omnivorous owl, as has been stated, wings its way to where the sparrows sleep.

All these facts, carefully reported by ornithologists in the field, have been carefully studied, and, as stated in the outset, eminent and conservative experts in this line of investigation now are prepared to prove that the end of the reign of the English sparrow has begun.

Few announcements of scientific men have ever been more enthusiastically welcomed than will be this interesting disclosure that the reign of the English sparrow is menaced. This bird's tyranny in America, Australia, and Europe has hitherto been complete. Conclaves of scientists, legislatures, and even parliaments have repeatedly devised unavailing campaigns against it.

From four to six families are reared annually by a pair of English sparrows. Not infrequently developing nestlings are utilized to hatch subsequent broods. Whatever its faults, this bird is devoted to its young. If one falls from the nest it is not abandoned. This fact led an ornithologist to compute the possible increase from a single pair of birds in ten years, assuming that the first and all successive parents managed to rear twenty-four young annually. The total

---

* Specially prepared for the SCIENTIFIC AMERICAN SUPPLEMENT.