Mr. G. P. BIDDER,—President,—said, that the Institution was much indebted to the Author for bringing this subject forward; and he hoped that the various points in the Paper would be freely, candidly, and impartially considered. Engineers would probably not enter with so much interest into the alleged influence of draining on the increase of the crops; but the branch of the subject most interesting to them would most likely be the effect of drainage on the arterial channels and outfalls of the country. The extent to which under-drainage affected the rivers was of particular importance. It was asserted in the Paper that under-drainage did, to some extent, augment the flow of rivers, and thus necessitate a larger water-way under bridges, which were already barely sufficient; in that point of view the subject was one of great importance. He trusted this question would be maturely considered, and that the discussion would throw considerable light on the subject. If the views put forward in the Paper were shown in any instance not to be consistent with recorded facts, he was convinced that no man would be more glad to be set right than the Author.

Mr. BAILEY DENTON remarked, that he had introduced the subject more for the purpose of provoking discussion among Engineers than with the object of advancing his own opinions upon it. Having practised under-drainage somewhat largely, he had experienced some dissatisfaction that there had not been a higher class of talent employed in the direction and inspection of drainage; he thought therefore, that the discussion would show that the question of the effect of under-drainage on the arterial channels of the country was worthy of the consideration of the Institution, and the result would be a more scientific treatment of the whole question in future. In the control of drainage by the Government, owing, perhaps, to the disinclination of the Landed Interest to see men employed of a higher class than those now generally engaged in the lower walks of agriculture, the subject of under-drainage had not received the attention which was due to it. He found, in his communications with the Government inspectors, that they were persons—he would say it with all deference to their special avocations—who were not fully competent to go into so important a question with the various engineering details bearing upon it. They had been, perhaps, selected from a class who were generally considered more suitable for the work than the Civil Engineers of this country, who were usually engaged in constructive works. Now he believed that this was false economy, and that it was much easier for an Engineer to descend to the lower grade of agricultural requirements, than for the agricultural agent to ascend to the higher science of engineering; and it was because he was so thoroughly impressed with the magnitude of the subject, and with the fact of its details and influences not being duly

appreciated, that he had ventured to bring it before the Institution.

He particularly desired to express himself clearly with regard to the second result of under-drainage, namely, that of strengthening the perennial springs. He was bound to say, that at an early period of his connection with drainage he entertained a different opinion to that now expressed. He had considered that the result of taking away so much water by under-drainage must be, to leave less in the land to be discharged by means of springs: he had stated that opinion publicly and in print, and he had since found those views quoted, with his name attached as an authority, in American and French papers. He could now only say, he regretted having ever so expressed himself, because, from his more recent experience, he had arrived at a different conclusion. He believed Mr. Charnock's experiments were correct in the main: and, that in the water economy of the country, draining the surcharged free soils would make a considerable difference, but perhaps not to the full extent, 13 inches, stated by Mr. Charnock. The experiments of that gentleman, however, considered in connection with his own observation and practice, had brought him to the conclusion, that the result of under-drainage must be to strengthen the main springs of this country.

The Rev. J. C. CLUTTERBUCK was not prepared to give a decided opinion on the point of the increase of the perennial flow of rivers caused by drainage. He was convinced that this part of the subject required much thought and consideration, as well as careful watching. He hoped that the discussion would lead to more attention being paid to the amount of rainfall in various parts of the country, the records of which were still very imperfect; in fact, information in general on this subject was still greatly in arrear. The Author had done good service by showing the necessity for more attention to that point.

Mr. Clutterbuck had paid much attention to the subject of the perennial flow of flood waters of the River Thames, as well as to the percolation of rain water, and its passage from the land to the river; his residence near the river Thames for more than thirty years, having afforded him a good opportunity for observation. The great body of the flood water was derived from the tributaries of the river, which, rising in the oolitic strata, received the flood waters of the Oxford, kimmeridge, and gault clays, but it was difficult to find out exactly how much rain fell upon so large an area. It had been observed that the floods in the Thames, near Abingdon, which used to reach their highest point in seventy-two hours, now reached that point in about thirty-six hours. He had noticed this for some time, and his observations had been confirmed by others. This was the case both in summer and winter, and he attributed it

to the increase of agricultural drainage, within the last twenty or thirty years. Before under-drainage had been carried out to any extent, the water used to rise in the soil to the surface, and did not until then flow away down the water courses and thence to the rivers. By close observation of such facts, the truth would be arrived at. Another point worth notice was, the influence of the direction of the wind on the floods. He presumed that the theory of rain was, that the vapour was brought from the ocean —the west and south-west winds bringing the vapour from the Atlantic, and the north and north-east winds from the North Sea. In the Thames an easterly wind, with the same amount of rain registered at Oxford, produced less flood water than a similar amount with a south-westerly wind; though something was due to greater evaporation, yet this was not sufficient to account for the difference. Besides it was remarked, that the Thames stream, rising in an easterly direction, brought down more water, in proportion, with an easterly wind, than streams flowing from the westward; and vice versâ with a south, or a west wind. It would appear, that as the vapours impinged upon the land, they expended themselves either in the western, or the eastern parts of England, as the case might be, and that when they reached the midland districts, such as Oxford, they gave a mean of the rain they brought with them. Hence the necessity of consulting many rain gauges, when calculating the amount of rain which would cause a certain amount of flood water, in so large a district as that drained by the Thames and its tributaries. It required at least 2 inches of continuous autumn rainfall, such as had occurred in the month of November, 1861, to saturate the soil so as to cause the drains to discharge. It was interesting to watch the floods in the Thames, and he believed that observations of their character would be a valuable addition, to the information contained in the Paper. Although he could not, without further research, venture to discuss the difficult point of the effect of drainage on the perennial flow of rivers, he should carefully ponder over the statements contained in the Paper, and by means of other observations, would endeavour to arrive at the truth. At present it was a problem on which he desired further and more ample information.

Mr. BIDDER,—President,—requested Mr. Denton to explain the mode by which the quantity of water which flowed from the land on which he experimented was measured; because, although this was only a small experiment, and thus totally inadequate to justify any general conclusions, yet every experiment which in itself was perfect, formed one of a series of facts on which some conclusions might be hereafter based. This was a question entirely dependent on facts; because, as regarded the effects of under-

drainage on the general supply of rivers, there were conclusions of a general character which to some extent had been modified; or at least there were those who proposed to modify them. As regarded the effects of under-drainage, it had always been assumed that the natural effect would be to increase the floods in wet seasons, and to diminish the supply to the rivers in dry seasons. With respect to the effect in dry seasons, he had not a shadow of doubt in his own mind; but as to the effect in wet seasons, a difference of opinion existed, dependent upon carefully-observed facts. It was therefore desirable that Mr. Denton should explain the manner in which the flow of water from the land had been measured; because, from well-ascertained facts on a more extended scale, different results had been shown. At the same time it would be wrong to conclude, because one set of observations did not agree with others, that that set was not correct *per se.*

Mr. BAILEY DENTON replied, that the discharge was measured by having two buckets gauged and painted inside with lines, the spaces between which represented imperial pints. The bucket was gauged, filling it with water, the addition of every pint being marked by a white painted line drawn along the edge of the water received. The time was ascertained by a stop watch, the observer standing for a certain period at the mouth of the drain. This was repeatedly done, in order to ascertain with the utmost exactness the time it took for the water to arrive at a certain mark in the bucket. That the quantity recorded was accurate he had no doubt, as he stood by on several occasions while the water was being measured, and thoroughly to satisfy himself had the operation repeatedly performed, so as to be able to speak with greater precision. Not only was he present himself, but he had a letter from Mr. Clutterbuck, the owner of the estate on which these experiments were made, in which he stated that he could entirely corroborate the accuracy of the results.

Mr. JAMES SIMPSON,—Past President,—remarked, that some of the conclusions put forward in the Paper were at variance with his own experience, although he believed, that in some isolated cases the proposition advanced, of the perennial flow of streams being increased by under-drainage, had been proved. Of the few instances which had come under his own observation, he would mention one, on the borders of Kent and Sussex, where the soil was a strong loam, with alternating beds of clay and retentive material, in sandy and porous soil, to a considerable depth. The extent of land drained was about 20 acres. The land rose from a stream rather abruptly, and at the bottom, contiguous to the stream, there was an osier ground, which, up to the period of its being drained, was kept wet by the flow of water from the land. Shortly after the drainage had been

carried out to a certain extent, a spring broke out in a depressed part of one of the fields, and a considerable flow of water issued. It was inconvenient to allow it to remain there, and it was led away to a ditch, independent of the water course which conveyed the water from the land to the osier bed. The flow of water became a constant stream, and appeared to be much increased. At first he thought some springs had been tapped from the land, higher than that operated upon, and that the drains were conveying water from other land than that which had been drained. Subsequently, however, from a more minute investigation, he was led to believe that was not the case; and continuing the observations, he perceived in the summer and autumn that the osier bed became quite dry, a circumstance which persons who had known the spot for fifty or sixty years never remembered to have occurred before. This induced him to investigate the matter still further, and from all the trials he was enabled to make, he believed the fact to be, that during the drainage operations, the thin stratum of clay which retained the upper water, had been penetrated, and conveyed the drainage over the land, keeping it in a continual state of saturation; that subsequently the water had sunk down into the lower and more extensive porous strata, and thus had enlarged the capacity of the sandy and porous bed, or reservoir, for the reception, or retention of the water, which supplied what might be called the new spring, and by these means had increased the perennial flow of water; the new spring having, in fact, become connected with the larger and more extensive water-bearing strata.

There were other cases very much like this, in which he had no doubt, in certain years, the perennial flow was increased; but in other years, especially in seasons of extreme drought, there was no increased perennial flow of water; but on the contrary, the drought was prolonged.

He might mention a case in contradistinction to the above, at Malvern, where some drainage operations were carried on, in order to increase the supply of water to a small farm and some cottages. The springs were opened, and by that means the flow of water was increased; and the springs which had theretofore supplied the farm and cottages yielded a considerable quantity of water until about the middle of June, 1850, when they became dependent to a great extent upon storage alone. The water was conveyed into a store reservoir, holding about 30,000 gallons. At first the supply obtained amounted to 1,100 gallons per day; but in ten weeks there was no water, the reservoir having become empty, and the springs having ceased to yield any water some weeks previously. That was a case in which the effect of drainage had been to open out the springs, to

drain the land, to let off the water faster, and to prolong the drought during a period of more than three months. Persons who had known the springs more than thirty years, assured him they had never observed them to cease flowing, although in dry seasons the quantity of water had been always considerably reduced.

There were many other cases to which he might refer; but there were few instances in his own practice in which the effect of under-drainage had been to increase the perennial flow. Generally speaking, he had found that the flow of water in rivers had not been increased by land drainage; but on the contrary, that in the course of years small streams had become dry which were never known to be dry before, and that the complaints of the agriculturists, of want of water on the higher lands, now recurred year after year, excepting in the wettest seasons.

Mr. JOSEPH GIBBS did not know whether the discussion was intended to be directed to the increase, or non-increase, since the introduction of drainage, of the volume of water in rivers, or whether it was only intended to elucidate the advantages of drainage generally, and its effect on the outfalls in particular. Looking at it, however, as a question of general drainage, he would offer a few observations on that division of the subject.

From his experience and observation, he could only arrive at the conclusion, that it was almost impossible to generalise with regard to evaporation, because the effects were so various, and the disturbing causes were so numerous, that results were difficult to arrive at. As an instance:—If water was exposed to the action of the air, the evaporation would be in excess; but, on the other hand, if evaporation took place in a field covered with vegetation, it would be at a minimum. Those cases occurred so continually, that the amount of evaporation from the surface of a large area of land, when considered with regard to the rainfall, could not be ascertained with accuracy.

He did not notice that the question of capillary action was touched upon in the Paper. If the drainage was too deep, the capillary action was weakened. If the drainage was not deep enough, the penetration of the air was not sufficient for good cultivation. His attention had been drawn to these questions for more than forty years. In his early days he had studied under Dutch Engineers, and had been taught by them valuable lessons in drainage; and the whole of his experience from that time to the present convinced him, that the Dutch system of drainage and of preventing the water from sinking too low, was the correct mode of treating land.

Touching this question he might, perhaps, be allowed to relate an experiment which he had tried some years since, and which

bore upon the effect produced by drainage. It was this:—He had a cistern of large size constructed with a material of a porous nature, like drip-stone, and of the depth of 2 feet 6 inches, in order to assimilate to that of an ordinary Dutch drain, which was from 2 feet 6 inches to 3 feet. Water was admitted by the lower part of the cistern, to represent the subterranean water surface, after drainage had been completed. The earth put into the cistern was the ordinary soil of a wheat field in good cultivation; vegetables, grain, and trees were then planted in it, and all flourished and grew luxuriantly. Another cistern was made in precisely the same manner,—the same conditions being observed, with this exception—that to this cistern there was an outer case, and that water was admitted between the internal and external cases, so that, instead of descending in the ordinary way of rainfall, it ascended, and was then evaporated from the surface of the soil. In the latter cistern various descriptions of aquatic plants and mosses were placed, and they all flourished, no air descending into, or mixing with the soil. After those crops were grown the operations were reversed, and the aquatic plants died, because the air penetrated downwards: whilst all the cereals and other useful plants perished in consequence of the water ascending. In the latter case it was evident that there was no capillary operation going on. This in one case was the condition necessary to create a bog, and in the other to occasion those operations of nature which always produced fertility. The importance of the air descending into the soil, in order that it should commingle with the moisture derived from capillary attraction, need scarcely be dwelt upon. But the usefulness of such an adjustment of the water-level did not depend on the evaporation of the water alone. The water evaporated by capillary attraction always left behind it a certain portion of sustenance for the plant; because by evaporation from the surface pure water alone was abstracted, leaving the useful materials brought up from the lower stratum for the sustenance of the plant. It was in that way, and where the water instead of being fertile was chalybeate, that the 'pan,' as it was called, found upon poor sandy soils, was formed. The capillary operations before described, left behind a material which produced the pan, or rough conglomerates, cemented with iron; and where that was the case, no useful culture could be carried on, until that pan was removed. All these details were of great importance. The general conclusion he had arrived at was, that drainage might be too deep, but it was indispensable to have it deep enough. Questions of this character could not be reduced to any rule, inasmuch as the depth of proper and judicious draining was dependent upon the nature of the soil. Still, even taking

into account the nature and character of the soil, the probable changes after drainage, and other circumstances, the limits were not very great between deep and shallow draining. There were as many advocates for deep draining as for shallow draining; but at the same time, it must be observed that, throughout the Low Countries, where the open drain represented the most perfect system of drainage, the fertility of the land was primarily dependent on draining; and there the water was rarely below 3 feet from the surface, in consequence of another operation much connected with this, namely, the operation of sub-irrigation.

Great improvements would doubtless be induced by the recent legal enactments, in providing proper outfalls and recovering large tracts of land from the state of swamps. These proceedings would be the means of regulating the courses of rivers; but at the same time there was no doubt that all these improvements would, by cutting off bends and making other alterations, bring the flood water more rapidly down the streams; nevertheless the general character of the rivers would be ameliorated, so far as available water for mill purposes was concerned. It was also important to look at the question of good outfalls on the sea-coast, because in flat districts great benefit might arise from attending to the marine outfalls. He thought that outfalls were too often referred to the contiguity of older works, instead of establishing good parallel outfalls, independently of the existing rivers. Nearly all the outfalls in the Low Countries were independent, were parallel in their sides, and did not open out into estuaries. Attention should be directed to that question, and it would be well that inquiry should be made as to where the sea outfalls might be best located. He was strongly inclined towards the adoption in all cases of a parallel exit, excluding all river water when charged with earthy, or sandy matter, and also excluding to a considerable extent the tidal inflow.

In answer to a question from the President, Mr. Gibbs said the standard depth of draining in Holland, in order to maintain the water in the drains below the level of the land, was 2 feet 6 inches, or 3 feet; but that was not a fixed rule. The water was sometimes raised 2 or 3 inches in the summer; and on meadow land, in winter, it was often raised above the level of the surface of the ground, for if a farmer got his land covered with water in the winter, and it became frozen, a certain amount of subterranean heat was preserved, and retained in the ground; and it was calculated that earlier crops were obtained by retaining that warmth.

Mr. EVANS had not had so much experience in clay countries as in soils of a more pervious character. The subject of discussion might be divided into two heads—first, the experiments them-

selves; and secondly, the deductions to be drawn from the experiments. Mr. Clutterbuck had corroborated Mr. Denton's remarks as to the care with which these observations had been made; but still there were probably many sources of error which might arise in an experiment of this kind, extending over a period of only eight months. In the first place, the effect of draining heavy clay soil was not immediate. It was some time before the drains got into operation, and a certain period must elapse before all the channels which opened out to those drains were fully formed. He was not aware how long the fields had been drained previously to the experiments being made, but he believed that the drainage had not long been completed. Another question which might interfere was, whether the land was lying fallow, or was covered with vegetation. A crop of turnips would in the autumn months absorb moisture, which under other circumstances would have gone into the ground, and even a crop of grass might affect the penetration of the water into the soil. It had been said that in these eight months there were only 10 inches of rain. Mr. Denton had stated that the average rainfall in that district was 13 inches. He thought they might assume, if 13 inches had fallen, the other 3 inches would have found their way down to the drains. But it was shown by Dalton's gauges, which Messrs. Dickinson and Co. had kept in operation for thirty years, at Nash Mills, that with the same amount of rainfall there would be different penetration in different years. Much depended upon the manner in which the rain fell. During slight showers, with fine weather intervening, there would be little penetration; but with heavy rain day after day, the ground would be saturated, and a great quantity of water would go down to the springs. In the years 1856-57, during the six winter months of October to March inclusive, a period which corresponded with six of the eight months to which these experiments referred, 11·96 inches of rain had fallen, and yet only 3·72 inches passed through the gauge, filled with ordinary surface soil. In the winter of 1857-58 there had fallen 11·81 inches of rain, and as much as 5·64 inches passed through the same gauge; showing clearly that the penetration into the soil depended upon the manner in which the rain fell. In the winter of 1858-59, with a rainfall of 9·64 inches, less than one-tenth of an inch passed through the soil to a depth of 3 feet. It was therefore obvious, that a great range of experiments was requisite to obtain satisfactory general results. Mr. Charnock had stated that the annual evaporation from a saturated undrained soil was 8 inches more than the rainfall. Practically, there would be difficulty in getting that amount of evaporation, as more water could not be evaporated than had fallen in the shape of rain; but, after all, in cultivated soils, it

was not so much a question of mere evaporation from the surface, as of the absorption by vegetation in summer. Mr. Lawes had shown that a grain of wheat, in growing to maturity, would take considerably more rain than its share, if it could get it; and in the summer months in free soils, on which vegetation was in progress, there was little, or no penetration through the soil. Scarcely any moisture would go down 3 feet, so as to reach the springs. It appeared to him, that deductions arrived at from such slight experiments as those of Mr. Denton could hardly be relied on, and it would be safer to trust to careful observation and general theory. The object for which the drainage of clay soils was undertaken was to convert heavy, impervious land into free soil, and to make it assume the same conditions as if it contained a large amount of arenaceous matter. The consequence of drainage was, that the land was more easily broken up, because it had become more friable, and was more pervious to air and moisture. But still there was a vast difference between the two characters of soil. Generally speaking, where free soil existed on the surface, it had a substratum of sand, or chalk, or other analogous formation, forming a natural storehouse for the water accumulated in it by percolation during the winter months, and that water was gradually delivered out in the summer months. In the case of a clay soil there was nothing of this kind, though there were frequently small spongy reservoirs on, or near the surface, from whence, however, there would be but very little flow in the summer months. In undrained heavy soil there were found springs of that kind, and it was mainly upon them that the rivers were dependent for supply, in addition to what might be derived immediately from the rains. The consequence of the clay soil being converted by drainage into a friable state would be, that in the summer months much more rain would be absorbed. It would take in nearly all the rain which fell, and would retain it for the purposes of vegetation; whereas in undrained clay soils the surface was cracked and fissured to a considerable depth, while the clay itself was comparatively as hard as a brick; and if a heavy rain fell upon the land in that state, a large amount of it was carried off to the rivers. His impression with regard to the drainage of clay land was, whatever might be the effect upon the floods in winter, and these would probably be increased, that in the summer months the flow must be diminished, and the irregularity of the flow of the streams, which was already too great, be rendered greater still. If the system, now so commonly pursued by Local Boards of Health, of converting rivers into common sewers, were persisted in, any diminution of the flow of the rivers, during the summer, would be attended with incalculable injury to the country.

Mr. R. B. GRANTHAM considered the Paper was of great

importance, as affecting a subject in which he had taken some interest, that of arterial drainage and outfalls. With regard to experiments in pipe draining, so few had been made, that they could hardly be trusted as grounds from which to draw any correct inferences. There were several localities which he could point out, in which it would be very useful that such experiments should be made. He might instance the Hainault drainage, which had been carried out by himself. The pipe drains in that case were conducted into the main arterial stream, the natural inclination of which would have caused far too great a velocity in the water flowing through it, had it not been checked in its course by a series of overfalls, below each of which the pipe drainage was brought out. A good opportunity for observation was thus afforded. These main pipes coming out at the overfalls drained a certain defined area on each side of the arterial stream; and proper rain-gauges being kept and observed in the locality, the exact discharge at each place might be ascertained, and compared with the rainfall. He hoped the new Drainage Act, in which he had assisted the Government, would prove of great advantage to the country. As yet they could hardly tell what its effect would be; but it might fairly be expected, that there would be a great opening for the engineering profession. The cases which would arise would require a peculiar kind of operation, more particularly with regard to the large tidal rivers. It still remained to be ascertained, how under-drainage would affect the rivers between the tidal level and the upper country, where the water would be sent down in great quantities by the improved formation of rivers, and from the pipe-drainage system.

Mr. EDWIN CHADWICK, C. B., would attempt very little on the mere technical portions of the subject. But the course of the discussion displayed wide differences of opinions, which might be ascribed to the different points and comparatively limited areas of observation, and to differences of conditions, such as must occur even to professional men of wide practice in drainage works. It appeared to him, that wheresoever the future was charged for results, or where absentees, or reversioners were made liable *in futuro*, or where public money was expended in works, there ought to be an independent examination of the works, as well as an audit of the expenditure, to verify the fact that they were of a quality to insure, and to be of benefit equivalent to, the charge upon future as well as immediate contributors. Several millions of public and private money had been expended on works conducted on different methods and conditions. He did not mean to suggest that such an examination as that which he advocated, as a matter of principle, was needed in this case, on account of any malversation, or malpractice—for he had heard of remarkably little absolute failure—all, speaking

generally, appeared to have been successful, though in different degrees. The earlier and ruder works had generally repaid the outlay in about ten years; the later, and better works, usually in about four years. Yet only a small proportion of the lands which required drainage had been drained, and a proper examination would tend to reassure and encourage owners and occupiers, and would, moreover, serve to show which of the various methods in use was the best under the like circumstances, and much would be learned for the improved direction of the large amount of future expenditure required. There were large agricultural facts as well as engineering facts and laws to be determined. For agriculture, the purpose of drainage was not to render land dry, but to regulate and adjust its moisture, commonly and generally by the removal of the excess of water; and it would also be frequently found necessary, at particular seasons, to supply deficiencies of moisture. He had long been told of facts such as those mentioned by Mr. Gibbs. In some of the fen districts it had been ascertained, that when the water table was maintained by pumping a few inches below, or above given points, too much, or too little, was done for certain cultures. The determination of such facts would be of agricultural importance. On the other hand, in works for the subsoil drainage of the sites of towns, where in order to prevent damp the object was to render the sites absolutely dry, in carrying drains, or sewers, through suburban, or market-garden cultivated land, there had, at some places, been outcries from the gardeners that they were injured by too deep drainage. On sanitary, as well as on agricultural grounds, he had recommended the abolition of open ditch drains, and the substitution of pipe drains for roads, as well as for fields; providing cess-pits, in the roads, for arresting the detritus. In most cases the surface of ground gained paid for the substitution. The experience of this description of road drainage would show, where it was properly conducted, that whilst it was best for the roads, it also served to provide outfalls for the subsoil drainage of the adjacent cultivated lands; and where the roads and public paths were close, in some strata, it did, for the adjacent cultivated land, almost all the work of drainage which it required. With respect to the question of outfalls, it would be found, as had been proved on some estates, where absolute marshes and swamps had been drained, that for advanced culture, and for the most active growth of vegetation at particular periods, as well as for the cheapest and most efficient distribution of manures, all the rainfall of the year would be required that could be detained for application by storage. As to the effect of the excess of moisture in lowering temperature, there had been important experience of the effect of its removal in elevating it, which seemed to him to warrant the expectation, that if the land

were generally and systematically drained, an elevation of some six degrees beyond the present average temperature of the country would be the result. There was, moreover, important experience to be collected from the improved adjustment of the sizes of small, as well as large pipe drains, to the service for which they were required. The drainage works of the larger proprietors, such as the late Duke of Portland, the present Duke of Northumberland, who had for some time expended as much as £20,000 a year on land drainage, and others, had been conducted under very intelligent observers, who could contribute highly valuable information. A proper inquiry, conducted by intelligent, impartial, and competent persons, could not fail to be productive of useful information for future guidance, and would probably provide a basis for the deduction of general laws, for which the scattered and fragmentary details now possessed, or obtainable by casual volunteer efforts, appeared to be wholly inadequate.

Mr. SAMUEL SIDNEY would make a few observations on the agricultural element of the subject. Up to the present time the question of drainage had not been of sufficient importance to attract much attention from the higher members of the engineering profession; but the statements of Mr. Evans showed, that at no distant period the accumulation of surface waters, rapidly poured into the brooks and rivers, would be so great as to require the best energies of the rising generation of Engineers. Facts were not wanting to point out how rapidly this period was approaching. Only about twenty years had elapsed since the attention of agriculturists was called to the principles of systematic drainage, and it was only about seventeen years since the horizontal machine for making drain-tiles, and which first provided cheap tiles, was invented.

It was about fifteen years since the Act for the first drainage loan of £2,000,000 was carried by Sir Robert Peel's government. That loan had an extraordinary effect, in first converting landowners and then tenant farmers to the new principles of agricultural drainage; but what might properly be called the 'Parksian' system had only been freely accepted by tenant-farmers during the last ten years. Within Mr. Sidney's recollection the subject of discussion at the farmers' clubs was, not whether the draining should be shallow, or deep, but whether land should be drained at all. At the present moment a farmer would not look at a clay farm, unless the landlord undertook to drain it thoroughly. In the course of the last fifteen years 1,000,000 acres of land had been thoroughly and systematically drained. There now remained about 21,000,000 acres of land that would pay for the cost of draining. It must not be assumed that the future operations would be carried on at the slow rate of the last fifteen years. At the commencement of that period, there were extraordinary

difficulties to be overcome before agricultural land could be reduced to the more profitable condition of dryness. In the first place the greatest difficulty lay, as he had before observed, in the prejudices of the landlords and the tenants: and here he might observe, in reference to what had fallen from Mr. Gibbs, that the practice in the Netherlands did not bear much reference to what was required in the great corn-growing districts of England. In the most pressing cases, they had in this country to deal with stiff clay soil, and they wanted to make it a free soil, to get rid of the rain and the springs fed by the rain. In the Netherlands they were generally compelled to grow such crops as would flourish on a rich damp spongy soil. Having convinced the minds of the people, the deep drainers had next to get the money,—at the rate of about £4. 10*s*. per acre. Government had lent £3,500,000 on annuities, which amount was in course of repayment; Drainage Companies had been formed which had lent £1,500,000; and the large landowners of the country, who had ready money to spare for investment, had been enabled, by a special act, to charge the money spent on draining entailed estates, with the repayment, for the benefit of younger children, or other legatees. The moral, the pecuniary, and the legal difficulties, having been thus diminished, it might fairly be expected, that in the course of the next fifteen years, a large proportion of the twenty-one million acres, still remaining, would be thoroughly drained. Thus it might be expected, that the surface waters would flow each year more rapidly and in greater quantity into the rivers, and that damaging floods would increase in number and extent. He had lately visited a part of the country which had always suffered from floods, and where the oldest farmers agreed in stating, that the floods became every rainy year more frequent and more injurious, because they came on more rapidly. Within the last two years steam cultivation had added another powerful stimulus, not only to drainage, but to the flow of water through the soil. Three, or four years ago, few persons believed that steam cultivation could be made profitable, but at the present time between three hundred and four hundred steam cultivators were at work, and the manufacturers were delivering them as fast as they could be constructed. The first effect of steam cultivation was to bring retentive clay soils into favour. These clay soils could thus be turned up five or six inches deeper than had ever been done before. With steam cultivation clay land was brought to a condition in which it parted freely and easily with the rainfall, allowing that portion of it to run into the drains, which was previously retained until evaporated. The action of the measure for improving arterial drainage, which was passed by Parliament during the last session, depended on the opinion of a majority of landowners; but landowners were not

Engineers, and therefore useful facts, on the subject of arterial drainage, must in some way be communicated to them. A professional investigation, geographical and geological, of the condition of the water courses and outfalls of the kingdom was imperatively required. At present landowners had often nothing better than the vague ideas of uninstructed people to act upon. He knew that commissions were not very popular,—they had deservedly acquired a bad name, from the way in which some of the early ones had been worked. He thought it must have struck impartial lookers-on as very odd, that while English Engineers were confessedly the first in the world, the Government rarely consulted the Institution of Civil Engineers, whose Council included all the most eminent men in the profession. This question of agricultural and arterial drainage was one which the Government might entertain if they selected competent advisers. He made these observations solely with the view of showing, that the works, about to be required for completing agricultural drainage, would be worth the attention and would pay for the services of the rising generation of Civil Engineers.

Mr. GIBBS said, the systems of agricultural drainage in Holland and in the stiff clay districts of England differed essentially; but the operations of those physical laws, by which the admission of air into the soil, and the extraction of water from it, were effected, were the same, whether they were performed by pipe draining, or by open draining. It must be considered for what purpose drainage was carried on in a stiff soil. When by the effect of drainage the air was enabled to penetrate into the soil, the soil itself changed its character. It would then hold only what might be termed the normal quantity of moisture, which was, really, the exact amount of moisture fit for agricultural operations and for the development of vegetable life; but clay soil, unsubdued by the effect of draining, held more than its normal quantity of moisture, and might be considered as being supersaturated. Draining rendered it only a moist soil, and the object of draining was to obtain land fit for agricultural purposes. He had seen evidences that clay was pervious to water in summer time, having traced small veins and openings caused by summer shrinkage to a depth of 10 feet, or 12 feet below the surface of the earth, and it was in such cases that nature performed the operation of causing the air to enter into the soil; but it came too late in the summer season for the purposes of vegetation. By draining the same clay soil, rain, air and heat were constrained to penetrate the earth, and thus to change and ameliorate its nature, by which means the advantage of an early season was attained.

Sir JOHN RENNIE had not been able to collect the whole of the

facts mentioned in the Paper, so as to express an opinion on them. Upon the agricultural portion of the subject he would not offer an opinion. With regard to the outfalls, no doubt the improvement of them, in districts through which large masses of water passed, was extremely important. He had been engaged in conjunction with his late friends, Mr. Telford and Mr. Robert Stephenson, in extensive works, in connection with the drainage of the low Fen districts adjacent to the Nene, the Ouse, the Witham, and the Welland, and in some of those cases the water had been reduced to 3 feet below the surface, which was considered sufficient. The important point, on which, as Engineers, he trusted they would agree was—that the getting rid of the water was not the only important part of the question, but that in all districts, where there was superfluous water at certain periods of the year, they should have a command of it, and not only be able to drain as low as was necessary, but to possess the means of employing the water for purposes of irrigation, when it was so required. In particular districts there was only a certain amount of rainfall, and this occurred chiefly during the autumn and winter. If the whole of that water was discharged at these particular periods, during summer, when there was less rainfall, water might be wanted, which frequently occurred. The object, therefore, of all drainage was to have a perfect command of the water; or in other words, they should have the means of getting rid of it to as low a point as was required, but at the same time they must have the power of supplying water when it was wanted for cultivation and for other purposes during dry seasons.

Mr. ROBERT RAWLINSON thought it very desirable, that they should be informed what crops were grown on the land which had been the subject of the experiments referred to. He had been informed, that according to the experiments of Mr. Lawes, in order to grow one pound weight of true woody fibre, two hundred pounds weight of water must be evaporated by the growing plant; and if drainage improved the land in one respect, by causing increased power of growth in plants, it also brought into operation a greater power of evaporation; and therefore it would be useful to know the kind and weight of crop that was grown on drained land. There was one fact, regarding the question of rainfall, which came under his notice during the previous week. The year 1861 was an exceptional season; and at Seathwaite, in Cumberland, up to December 5th of that year the rainfall was stated to have been 171¼ inches; during November it was stated to have been about 35½ inches. At Keswick, only 9 miles distant, it had been about 13¾ inches. That was the heaviest recorded rainfall that had occurred in that district for fifteen years. As to obtaining a command of subsoil water, it occurred

to him, that on large estates having a good fall, the upland subsoil waters might be utilized, and not as at present be passed directly away into the outlet. If large districts were properly laid out, the upland waters could be made to irrigate the lower-lying land, down to the lowest point. Parallel drains and reservoirs might economise drainage water, so as to be made to cover terrace after terrace of any adjoining lower lands.

Mr. G. W. HEMANS remarked, with reference to the question of the increased flow of rivers from drainage, that extensive operations had been carried on in Ireland with public money. Unfortunately, the works had not been judiciously laid out, and disappointment had resulted. It was therefore desirable, that any measures which might be thought advisable in England should be conducted in a different manner. It was notorious, that the waters in the great valley of the Shannon had been much increased by the flow from the uplands. Shallow lakes and bogs, presenting large evaporating surfaces, had been drained, and had ceased to exist, and the upper lands were therefore improved, but of course more of the rainfall came down to the river. At the same time the bed of the river had been improved, and efforts were made to preserve the navigation, and to provide for the increased discharge of water from the uplands; but it had hitherto been found impossible to do so adequately, so as to meet the discharge from the upper country. A public meeting had been lately held, for the purpose of requesting the Government to remove weirs and to construct other works, in order to provide for this increased discharge of the upland waters. As far as his experience went, he had no doubt that the flow of the river had been increased by the drainage of the uplands.

Mr. T. HAWKSLEY did not think, that agricultural drainage was a topic which particularly interested a great number of the members of the Institution; but he believed that, at no distant period, many Engineers would be engaged in practical operations under the provisions of the Act of Parliament passed during the last session, known as "The Drainage of Land Act"—an Act of momentous importance, which would not only create a great revolution with regard to the present exclusive rights in landed property, but would also extensively affect the public rivers of the kingdom. Therefore, under these circumstances, however small might be the general interest which attached to the questions directly raised by the Paper, it was certain that all Engineers had, in the future dispositions which might be needed under this first parliamentary enactment, a great and special interest.

The Paper had touched upon almost all the subjects on which the agriculturist could be called on to express an opinion. Mr. Hawksley, therefore, would rather draw attention to those large

engineering and physical features which interested Engineers in their practical dealings with rivers and outfalls, and the influences which affected the course of their flow,—of rivers and their ordinary volume—their augmentation in floods—their diminution in droughts —and their mechanical agency.

The Act recently passed, was one which would more or less, according to the extent to which it might be carried out, seriously affect all the rivers and streams of the kingdom. It was no less than an Act to empower certain commissioners to deal with all the sources of water in the kingdom; and it proposed not only to give power over all streams, but also to confer, by a certain process, and that a very rapid one, the right on a public Board to remove mills, and to destroy mechanical power, in a way which, he believed, had never been practically attempted before.

The Paper had brought some apparently important experiments before the Institution. They were not important because of their magnitude, nor because of their general application to the condition of the water sources in all parts of this kingdom, but because they seemed to initiate a method of treating the subject which must be considered as in some respects fallacious, and, therefore, it was desirable, on the threshold of the inquiry, to express an opinion on that subject, lest it should be said that this Institution had concurred in the views which the Paper had enunciated. Mr. Hawksley did not mean to say that, in the particular case which Mr. Bailey Denton had introduced, he had made mistakes, or had drawn erroneous conclusions; but he did mean to say, that the instance was a very exceptional one, and that general conclusions drawn from such an instance would lead to great and important mistakes.

The instance which Mr. Bailey Denton had given was that of a portion of a farm at Hinxworth, in the neighbourhood of London, and he had drawn his conclusions from the fall of rain in a somewhat exceptional year, upon a surface partly of chalk, and partly of green sand, with also, as he understood, an outcrop of gault clay. It appeared that these experiments were made in the winter months, between October and May, in the year 1856-7. Now it so happened that in those months there was comparatively little evaporation, while the months in which there was the greatest evaporation were entirely omitted. Moreover, that was a year in which the rainfall was considerably below the average; and, taking these two circumstances into account, the deductions drawn by Mr. Bailey Denton, with regard to ratios and proportions must, he thought, be deemed erroneous. Besides, these experiments were made in a part of the kingdom where there was almost less rainfall than in any other locality, excepting in the Fen districts and the extreme east coast. The consequence was, that

any conclusions drawn from these data would not apply to at least three-fourths of all England; for while, as a rule, the evaporation from the surface of ordinary land, in the latitude of 52°, might be taken to be about 14 inches, and the rainfall in the centre of England and in the same latitude at only about 24 inches, leaving about 10 inches ordinarily to penetrate into the ground and to flow off by the surface, on the western side of the kingdom the rainfall was from 36 inches to 50 inches, whilst the evaporation was no more than at Hinxworth. By penetration into the ground he meant penetration into a chalk surface; and of course in other places where there was not chalk, or an equally open soil, a part penetrated into the ground, and a part passed off as surface water. But in the parts of the kingdom to which he alluded, large portions of the water, perhaps as much as 3 feet in depth, would partly penetrate into the ground, and partly—the greater part indeed—flow off by the surface.

The ordinary conditions were, therefore, very different from those expressed in the tables given in the Paper; and in drawing general conclusions from these limited experiments, he was afraid professional men would commit considerable errors in their practice as hydraulic engineers.

Then, again, there were great differences of rainfall in different years. In some years the rainfall was a minimum, and was not more than half of the maximum, but the penetration into the ground would not greatly differ in the two states of circumstances. He did not say it would not differ, but in many soils it would not greatly differ. It was known practically, that in large portions of the west part of the kingdom, nearly all the water ran off by the surface, the volume of spring water being quite insignificant—not a 10th, a 20th, or a 30th part of the rain that fell. Under those circumstances, the tables given would lead to erroneous conclusions.

The Paper had also directed attention to this fact, that under the new Act it was proposed, and under the operation of that Act it would be effected, that large areas of ground, according to Mr. Bailey Denton, as much as 23 millions of acres, would, in some way or other, be dealt with by under-drainage. It was assumed that this operation would either not destroy the rivers, or that it would improve them. Now, Mr. Hawksley could only understand rivers as being 'improved' when they were rendered steadier, by the water being made more capable of being utilized, either for mechanical, or other practical purposes, or by being better fitted for navigation, or by being in some other respects made more useful. He believed the experience of all who had been engaged in practical operations connected with the collection of water was this, that the more the land was under-drained, the more

the irregularity of the streams was increased. He did not mean to say that there were not exceptional circumstances, and that cases might not be pointed out, where the contrary might be the result, in a particular soil which should receive a large volume of rain-water rapidly and give it out slowly. There were, indeed, cases of that kind in the vicinity of London, in which the chalk received large quantities of water, in wet seasons especially, and which gave it out slowly by the springs. That, as a matter of course, was a condition under which the natural under-drainage of the chalk improved the régime of the river; but the circumstances would be very different, under any other condition. Let the case be assumed of land being so under-drained as to make it capable of receiving water more rapidly, and that by this underground communication, the water was enabled to get more quickly away. The consequence would be, that the operation would contribute largely to the volume of the rivers for a short time, until the soil was exhausted of the redundant water. Under these circumstances, the river would be filled to overflowing at one period, and at another period the same river would be in a state of extreme and long-continued drought. That was a condition, which would neither be good for mechanical power, nor beneficial to navigation; and as regarded the landowner, it was manifestly often worse than the previous condition, because there would be floods on low lands, where there were no floods before, and droughts on high lands where a certain quantity of water should be kept for the supply of cattle, and for agricultural purposes. He could also state this broad corroborative fact, that within the comparatively short period of his own experience, as an Engineer, a perceptible change had taken place, as it had now become necessary to make larger reservoirs for the collection of water for the supply of towns in drained districts, and to hold a greater supply than had been requisite twenty, or thirty years previously.

There was also another condition of things worthy of serious consideration. Was nearly all the mill power to be taken away? He might state, as a curious fact, that proposals had already come before him for destroying mill power under this Act: though it had not yet been put in operation, landowners were already proposing to avail themselves of the powers of the Act against their neighbours; and therefore he was in possession of some of the results to be brought about by the Act when it came into operation. This was the state of circumstances as to the mill power of England. Just now it was, or very recently it was, at what might be termed its minimum value, and that had been in a great measure owing to the undue and excessive quantity of coal which had been raised. But whilst there had been so much coal raised for home consumption, enormous quantities had been sent abroad,

and there had been lavish use of it in manufactories and in private families. There were now raised and used more than 100 million tons a year, and that quantity was continually increasing. The result must, however, necessarily be, that all the cheap beds of coal would be speedily worked out, and that the price of coal would be greatly increased. It was already increasing slowly but steadily, and he believed from the cause he had mentioned, viz., that in many cases the cheap seams had been worked out, and that consequently deeper explorations had to be made at greater cost to the mine-owner.

Under these circumstances the water power of the kingdom would become more valuable. He did not say speedily; for he was looking at the question in a national point of view; and he thought it was a duty to conserve the water power of this kingdom, for the many purposes for which it would be wanted in the course of another half century, and especially in operations more, or less directly connected with agriculture.

There was a provision, in this Act, of a most curious kind. It might be said that it had followed a precedent, but when was the precedent created? Only during the previous year; and the peculiarity was this—that the Act might be brought into operation at the instance of the few, while the defeat of the attempt to bring it into operation could only be by the combination of the many. The Act having to be carried into effect, in this peculiar manner, under the sanction of a central board, it might be presumed that it would be put into general operation, and no doubt the Engineers would be largely engaged in these matters—either on one side, or the other. The course of proceeding was this: The Act might be proposed to be brought into operation for the purpose of removing mill-dams, weirs, and other like "obstructions:" this was going a long way, as anything might be called an "obstruction" which interfered with the run of the water. How was this generally to be dealt with? In this way—the objecting party was first to submit to an arbitration on the question of "principle." He was to submit to two arbitrations, and to bear many of the costs of the two. He was first to have an arbitration upon the principle, whether, for instance, his injury was capable of being compensated by money: not the price to be paid. He should like to know (with one, or two very exceptional things) what case there was which could not be compensated by money. The consequence was, the principle on this point must in general be decided against the objecting party. Then he was to be subjected to the tender mercies of another arbitration, which was to be conducted under the Lands Clauses Consolidation Act, to ascertain what remuneration he was entitled to receive, for, it might be, the entire destruction of his property. Now he believed the system of arbitration, as arbitrations were usually

conducted, was the most expensive engine known to the law of this land. He had himself been intimately connected with arbitrations of the most absurd and cruel kind. The last was of this nature. He would not give names, nor cite the instance except in its results. A claim was made for a large sum:—£20,000. The claim was disputed, and the case went to arbitration, in the manner provided for by the Lands Clauses Act. It was referred to two arbitrators with an umpire, who was a legal man. The result was an award of £3,000, the costs on one side being £8,000 and on the other side £5,000. Now he thought an Act which was to be brought into operation in the manner he had stated, with two of these engines set to work upon the poor resisting proprietor, was very likely to kill him outright.

But there were more serious matters, in other respects, than even those which he had mentioned. Under the operation of this Act, if a gentleman wished to drain his land, that land having been purchased at a price due to its unsatisfactory condition, he said, "I cannot make the best of my land, for which I have paid such a low price, unless I can do something with my neighbour below to compel him to let my water run through his property." The man above then set this Act in motion, and under its powers obtained a right to a new and legally created servitude in, or over the land of the owner below him. Mr. Bailey Denton would probably say, "We must drain in the manner pointed out by this Act." He dealt with no less than 23 millions of acres: but in different ways. He estimated that 11 millions had retentive soil, and they were to be dealt with by pipes which were to be laid at distances from 25 feet to 27 feet apart over all those acres, and that there were 12 million acres of what was called free soil, and these were to be dealt with by a disposition of pipes at uncertain intervals and at considerable depths. It had been said that by lowering the water in the Fens to a depth of 4 feet, the cultivation would be improved. Now Mr. Hawksley had incidentally something to do with the cultivation of the Fens, and he knew that in large portions of the Fens it would be very detrimental to lower the water in dry summers below 30 inches from the surface. He did not say that this was universal, but over a large area of the Fens that was known to be the fact. At present the farmers had to sink down 7, 8, 9, 10 and sometimes 14 feet, to bring up marl to spread over the surface of the peat, for the purpose of consolidating it, and rendering it capable of retaining moisture. And then what happened? In the course of two, or three years the marl was found to have gone down the depth of a foot, or more, and it went on sinking, in the course of years, to 6 or 7 feet deep, and then the process was to begin the work over again. Of what use then, he asked, could this species of

drainage be there? Only to make the superficial soil drier and lighter than it was at present. Taking, for instance, the land from Spalding towards Boston, this species of draining would be of no use. It would in fact be seriously injurious, for all that was necessary was to keep the water just low enough to allow the surface soil to become warmed by the sun, and just high enough to feed the plants with the necessary moisture, by capillary attraction from below.

Then, with regard to a large portion of Cumberland—the mountain land which there laid upon rock. Of course the species of drainage recommended would be of no use there—and so he might say of a great many other instances which occurred to him: he said nothing against Mr. Bailey Denton's theory of drainage, as applied to tracts of land for which it was fitted, but he objected to it as a general proposition, and therefore as a method to be applied to many other kinds of land which must be included within these 23 millions of acres.

Then as to drainage by pot pipes: that was an excellent mode of drainage in general, but it was attended with difficulties in particular cases, and it was frequently not so perfect as many other modes, better adapted to the resources of particular districts. In some cases when draining to the great depths, advocated by Mr. Bailey Denton, the expense became too great for many millions of acres included within the assumed area. If, on the other hand, the drains were shallow and the drain-pipes were small, the roots of the plants would get into them and would spread there like a seaman's swab, and in consequence the work would soon fall, and would have to be done over again. Therefore, he contended, that this sort of uniform operation would not answer: he did not say that he attacked it—but he endeavoured to express himself thus, at this early period, to prevent any general system, or code being adopted, or recommended by a Central Board, and so being carried all over the kingdom. What he contended for was, that every Engineer should be left to the unfettered exercise of his own skill and judgment, in all these cases, in order that he might advantage his employer, to the best of his ability.

He wished now to add a few words on the general engineering question; and knowing how difficult it was to deal with figures, in a discussion of this description, he had prepared a diagram, which represented what he believed to be some important facts with regard to the rainfall and evaporation, and the quantity of water flowing off large areas of land, on the western side of the kingdom; and what he was now about to say would apply, in a greater or less degree, to certainly 12,000 square miles, or 15,000 square miles of the area of this kingdom. In this diagram there was

recorded, by blue lines, the average amount of rainfall for every year, during a period of thirteen years, and by red lines the amount of loss by evaporation, and the distance between the red and the blue lines represented the quantity of water which ran off the ground. The Paper referred to a case in which the rainfall for eight months was stated to have been only 10 inches, and probably in that year the rainfall for the whole twelve months did not exceed more than twice that amount. In the case alluded to the average rainfall was more than 4 feet, and from year to year during the whole of the thirteen years, it fluctuated very greatly; but, on the other hand, the amount of water evaporated from the surface of the land was much more nearly uniform; and what would appear surprising at first was, that in the driest years the evaporation was the least. That arose from the fact, that although the power of evaporation was then the greatest, yet the water was not present to be evaporated: and the consequence was, that evaporation in the dry years was less, considerably, than it was in the wet years. Now in this case it was necessary to provide for carrying off more than three-fourths of all the water that fell, and that too principally by the surface channels; for it was impossible in a case of this kind that, by any means of under-drainage, the water should be let down below the surface of the earth so rapidly, as that a large portion of it would not flow off by the brooks. The inference, then, to be drawn from this was that Mr. Bailey Denton's data, valuable as he admitted them to be, with reference to chalk districts, were not generally applicable over the whole surface of the kingdom.

Then as to the question of mills. If the process recommended in the Paper were to be brought into effect all over this kingdom, the result would be that, for the sake of very minor interests, nearly all the water power would be destroyed. Much of it was now exceedingly valuable; and it would become more so as coal became dearer. Even now in the less accessible agricultural districts, it was almost indispensable for grinding corn, and for other similar purposes.

The process which Mr. Bailey Denton desired to bring into operation was, not only to make the pipe and other drainage relieve the land, but also destroy the mill dams. But on the other hand, what Mr. Hawksley insisted upon was, that it was wholly unnecessary, in the majority of instances, to adopt such a course, because, as compared with the large areas of the country, the tracts that were affected by mill-dams were very small. Assuming that, in some instances, the water was raised by the dam above the adjacent land, and that a few meadows and low-lying lands were affected; it was quite clear, that in the majority of these instances, the drainage might be effected, independently of

the mills, by making side-drains, and carrying the water below the mill-tails. All he wished to express was that, inasmuch as an Act had been passed with extraordinary powers—such powers as had hitherto not been known in English laws—that those powers should be carried into execution with great discretion, and with a due regard to the great present and prospective interests which were liable to be affected by it.

Mr. G. P. BIDDER,—Past-President,[1]—observed, that he differed very materially, in some respects, from the views advocated in the Paper; therefore any observations which he might make would be simply with a view of having the subject discussed solely with reference to its merits; but whatever difference of opinion there might be, to Mr. Bailey Denton was due the credit of having introduced a subject of great interest.

The members were indebted to Mr. Hawksley for the pains he had taken in bringing forward and criticising the enactments of an Act of Parliament which was passed last year. Mr. Bidder differed from those who thought it unnecessary that Engineers should study and discuss the laws of the country which affected their profession. He need hardly appeal to those members who were actively employed, to confirm his statement that, although they might be mainly engaged on mechanical points, yet fully one-half their time was occupied with questions political, legal, and social; and it was therefore incumbent on them to a certain extent to know the general bearings of the law, on questions of this importance. As to the Paper itself, he was bound to say, that he felt compelled to differ from the Author as to the accuracy of his facts, or that which should have made the facts important and useful. He would not now discuss the purely agricultural question, whether drains were better at the depths of 3 feet, 4 feet 6 inches, or 5 feet. Those were questions which would in time settle themselves, as each condition would have reference mainly to commercial considerations. The question of the depth at which water could be drained off, below 3 feet 6 inches, he believed to be wholly immaterial; therefore it was more a question of cost, which would depend on the nature of the soil, the inclination, and the locality. But with reference to the general question of draining land, particularly clay land, it was necessary to consider the importance of drainage, not only in an agricultural point of view, but also as it affected the rivers. Now the value of the Paper depended, as far as it went, upon the accuracy of the tabulated account of the observations. He had previously addressed a question to Mr. Bailey Denton with a view of ascertaining in what way the flow of water,

[1] Mr. Hawkshaw had been elected President before the conclusion of the discussion.

had been tested, and he must confess that the impression made upon his mind was not very favourable, when he heard that the water was measured in buckets with chalk marks round the inside of them, especially as the results were very different from those which had come under his own observation.

If the tables were correct, there had flowed from this land in the eight winter months more than two-thirds of the rainfall. Now this was so different from facts within his own knowledge, that he felt there must be some other fact withheld; when he said withheld, he trusted it would not for a moment be imagined that he implied that Mr. Denton had not communicated all he knew; but he thought there must be some fact which had escaped notice, and which it was most material should be ascertained. As far as Mr. Bidder's own knowledge and experience went, he knew no case, under any circumstances, in which two-thirds of the rainfall had ever been traced to flow from the land. It would be in the recollection of the members, that a very searching inquiry took place with reference to the drainage of the metropolis. An enormous number of experiments were made upon the rainfall and the flow of the sewers; and, to place the matter beyond dispute, some of the sewers of the metropolis were walled up, and every precaution was taken to confine the rainfall over a given area to distinct lines of sewers; and in dense parts of the metropolis, where the rain fell on slate roofs and paved back yards, almost every particle of water would find its way into the sewers; yet the whole of the experiments made by all parties, however antagonistic in other respects, coincided in this fact—that one-third of the rainfall, even in London, escaped observation, and never passed through the sewers at all, and in the suburbs the discrepancy was still greater. Such were the results in the metropolis, verified by observations of the most minute and extensive character. Now Mr. Bidder had observations accidentally coming within his own knowledge, which went far—he would not say to invalidate the results given in the Paper—but which showed, if they were correct, that some circumstances must have escaped Mr. Bailey Denton's observation. The land which Mr. Bidder possessed at Mitcham, lying on the south side of the Wandle, had been drained for some years. The drains were not so deep but that they would readily fill. In draining he allowed depths of 32 inches for grass land, and 36 inches for ploughed land; but from January until November, 1859, not a drop of water went off the land, through the drains, into the river; and from October to May—corresponding with the months in Mr. Bailey Denton's tables for 1856-7, but with 14 inches of rainfall as contrasted with 10 inches—not a drop of water went off the land through the drains; and it was not till the beginning of September, 1859, and November in the same

year, with nearly 9 inches of rainfall, that any water came into the drains, and was discharged by them into the arterial channels of the country. This was so different a state of things to that quoted by Mr. Bailey Denton, that it would be most unwise to arrive at any conclusion on the subject, until observations were made of a much more extensive and universal character, over a more lengthened period of drought and rainy seasons, and upon greater varieties of soil, than any which had been hitherto brought forward.

With regard to evaporation, during the period he had referred to, as much as an inch of rain sometimes fell in an hour or two, and the ground absorbed it all; it would be erroneous to measure the evaporation by the difference between the rainfall of a district and that which ran off. The evaporative power of the soil could not be so measured. It depended upon a variety of circumstances. Before the evaporative power of the soil could be measured, the moisture must be supplied. Take the case of a turnpike road: in a hot season there was no evaporation; but if the road was watered two, or three times a day, it all evaporated; and if there was a large traffic, like that on a Derby-day, it would evaporate every two, or three hours. Therefore, in quoting the experiments of Mr. Charnock to show that the evaporation exceeded the rainfall, the evaporative power of the ground only was shown: and it would not be correct from that to assume the evaporative power in any year, that there should be 20 inches of rainfall with 16 inches of evaporative power.

It appeared to be agreed that, in dry seasons, there would be less water passing into the sewers, when the land was undrained, than when it was drained—he alluded to clay lands. The question limited itself, therefore, to wet seasons. With regard to that, it was necessary to see whether all the circumstances were stated, in order to ascertain the amount of the overflow from the land into the rivers. In lowering a lake 2 feet, or 3 feet, there would be the same flow from the lower level as at the higher level. In land the level of the water in the soil was only lowered. To what extent would the evaporation be influenced? because evaporation was the only other element which would disturb the quantity going into the rivers. The whole rainfall passed either by gravity into the rivers, or into the clouds by means of evaporation. There were many questions which affected this. In clay lands which were not drained, particularly grass land, the surface became what was termed 'baked,' and from a surface in that condition there was not any evaporation. On the other hand, the same field when under-drained would never become so baked, and evaporation percolated through the ground by means of the under-draining. He would also allude to a case where 9 inches of rain fell, in September, October, and

November, before the land became saturated, and that was nearly half the average rainfall of the county of Surrey. If that were so, the impression on his mind was, that unless in exceptional seasons like that of 1860, where there would be 6 inches of rainfall in June, as contrasted with no rainfall in 1859—taking the average evaporative power of the soil of the kingdom—even in winter seasons, the quantity of water which would be found, after all the evaporative power of the soil, would be less in land that was drained than in land which was undrained. He did not wish to dogmatise on that point; but he was of opinion that, before legislative action could be taken, more extensive investigations should be instituted than had hitherto been made, to settle a question of that importance; because, as Mr. Hawksley said, it was a question which affected not only the mill-power of the country, but also the chemical condition of our rivers; for, although when the rivers were well filled they would admit of a certain amount of pollution, yet if they were, as was the case in 1859, seriously reduced in the amount of their flow, that pollution, which in ordinary seasons might pass away without deleterious effects, must become poisonous.

He made these observations, not with the view of pretending that the opinions he had advanced were deserving of particular notice, but to point out the fact, that at present the data possessed, as regarded evaporation, and the evaporative power of the soil under all conditions, were insufficient to determine the question with satisfaction to the Institution, or to the public.

Mr. J. H. LLOYD stated that he was a director of a Lands Improvement Company, and in that capacity had turned his attention to the effects of under-drainage, not only in its agricultural aspects, but also as respected the arterial channels of the country. He did not think it possible to overrate the importance of this question, and he hoped that the Members of the Institution would by no means think it unworthy of their serious consideration. Sooner, or later it must force itself upon the attention of scientific bodies. It was quite idle now to suppose that the operations of drainage could be arrested. The beneficial effects had been so sensibly felt, so universally acknowledged, that even the stolid farmer of England—long waiting to be convinced—had found and admitted, that it was his interest to have his land well and thoroughly drained; and it was a fact within his own knowledge, as it would be within that of Mr. Bailey Denton, that whereas agricultural tenants were formerly opposed to drainage, and denied its beneficial effects, they now exacted as a condition from the landlord that it should be carried into effect, offering at the same time to pay an additional rent equivalent to, or even greater, than the annual charge created for the improvement. It

was therefore impossible to suppose that the process could be stayed. Drainage would go on, wherever it was required; and whilst there still remained so much land to which it could be beneficially applied, the operations might be expected to be practically without limit. The Society of which he was a Director was, alone, expending at the rate of £300,000 a year in improvements of land, a great portion of which consisted of drainage; and other Companies were, he believed, in full activity.

It would be beside the question immediately before the Institution to go into any elaborate consideration of the mode by which the beneficial results of drainage were brought about. It might now be taken as an ascertained fact, that the effects, as well in agricultural production, as in an improved sanitary condition of the atmosphere, were most beneficial; and that, whatever the indirect effects in other ways might be, drainage must and would be continued. Taking that as a fact, then came the important consideration —were the operations, in doing such great good agriculturally, producing mischief in any other respects?—were they, by letting off the water previously lying, not only idly, but mischievously in the land—were they, in so doing, working injury in other ways, and if so, what remedies existed, and how and to what extent could they be applied for abating, or mitigating that injury? And here came in the province of the Engineer, because he it was who was to consider, and to help others in considering, the best way of effecting this object, with the least amount of detriment, or inconvenience, and with as little of arbitrary interference with the rights of others as the circumstances permitted. That was the problem to be solved, and it was with reference to that problem that the present discussion had been invited.

Mr. Bailey Denton had endeavoured, by a series of experiments upon a limited area (as must necessarily be the case when experiments were individually conducted), to ascertain the true effect of under-drainage in increasing, or in diminishing the supply of water in the streams and arterial channels. And although it might be conceded to Mr. Bidder, that the experiments were not by any means conclusive, and that being conducted on so limited a scale, and under such special conditions, they were perhaps insufficient to afford data from which any general conclusions could be drawn, yet it could not be denied that the Paper was a valuable contribution to the knowledge of the subject, and it established some important facts. He could not, however, give an entire assent to the deductions sought to be established from those experiments. His own observations and inquiries led him to the conclusion, that the apparent effect (for he spoke guardedly) of under-drainage, so far as it could be traced, was this: that although the quantity of flow into the rivers was not sensibly affected, yet the regularity of

the supply had been materially disturbed. He believed the fact to be, that the quantity of water discharged into the arterial conduits of the country had, in wet seasons and during the period of floods, been augmented, and that in dry seasons it had been diminished. Whether that was a fact immediately and solely attributable to drainage was questionable; but of the fact itself there could, he thought, be no reasonable doubt.

In the case of the Trent, the Derwent, and other rivers of like character, he had heard that the owners of mills on those streams, who were the persons most directly interested in this question, and had better means of ascertaining the facts than others, alleged that the quantity of water in flood seasons was liable to large and sudden increase, whilst the normal flow in dry seasons was rendered still more scanty than before. Rightly, or wrongly, they attributed the consequence to the drainage operations; and the fact, if true, was most important, also, to owners of land in the valleys. If it was true, as he believed it to be, that the flood-line in the valleys had risen to a higher level, whilst the perennial supply of the springs in dry seasons had been diminished, it was a fact to which attention must be directed; and he thought that, reasoning *à priori*, there were sufficient grounds for supposing that the fact would be so. Nature, left to herself, had provided, that the water which was carried down from the higher grounds stored itself in various ways, partly by passing into underground reservoirs, from whence it issued in the form of springs, and partly by forming pools on the surface, or saturating low-lying hollows, from whence it passed off gradually by overflow; and thus a regular and tolerably average supply was secured through the whole year. But by under-draining, and thereby forming artificial conduits for carrying off the water, these sources were tapped, and the store of water held in the ground was carried off more rapidly. Indeed, to effect this was the very object of drainage, the principle being, that water held in saturation in the land interfered with the productive energy of the soil, and rotted vegetation at its roots. It was to relieve the soil from this excess, and to form a cellular mould, through which the air and water could pass freely, that drainage was undertaken.

If this assumption was erroneous, the whole system of drainage was wrong, and they were doing no good. It must be taken therefore as a fact, established by *à priori* reasoning, as well as by actual observation, that the water passed off more rapidly, and consequently that at the time of the greatest rainfall, when the natural flow would be greatest, they helped that flow, which was augmented by means of the artificial channels provided by drainage, and thus that greater floods were occasioned than had previously occurred. The effect of this upon the mills situated on

rivers was very serious. Alluding only to a single instance—in the well-known Belper Mills on the Derwent, an addition of 150 H. P. of steam was found to be necessary to the water power which had previously been sufficient. To the mill-owner regularity of supply was as important as abundance. The fact was, that by the process of drainage immense good was done, by increasing the productive capabilities of the soil, to an extent inconceivable by those who were unacquainted with the ascertained results, and by improving the sanitary condition of the district, by carrying off the miasmatic vapours which were more, or less generated in all undrained localities. But having done that good in one direction, they must nevertheless provide against the mischief which might be created in another direction.

He would not pretend to analyse Mr. Bailey Denton's tables of rainfall and discharge; but he would remark, that there were not only the ordinary physical conditions, but also meteorological facts to be taken into consideration, before they could ascertain correctly the actual proportion between the rainfall and the outflow; but assuming the fact to be as had been stated, then came the practical question, what was to be done? It had been truly said, that this was a matter of national importance, which must force itself sooner, or later upon the attention of all persons interested in these beneficial processes. If the effect was to flood the lands in the valleys, and to stop the mills, it became necessary to consider in what way that mischief could be remedied. Accordingly, a body of gentlemen interested in agricultural improvement had formed themselves into a sort of association, for ascertaining the facts and applying the proper remedy. That body had in the last session of Parliament brought the matter under the notice of the legislature, which resulted in the passing of an Act, to which attention had already been drawn. Mr. Lloyd was aware that he was trenching upon legal matters, but he was speaking with reference to the general interests of the public, and not of the merits of this particular Act of Parliament. He did not purpose to deal with the subject, however interesting, or important in itself; but he might be permitted to say, it was a matter of engineering science, falling peculiarly within the province of the Institution to consider whether, and if so, in what manner, an evil of this kind, viz., the sudden accumulation of water in the valleys, producing floods at one time, and its undue abstraction producing drought at another season—could be remedied by the application of engineering skill and science. All questions of arterial drainage belonged to the province of the Engineer. And there was the still larger question, which had scarcely been adverted to, that even when the water had been got rid of locally, the mischief would not have been

entirely cured, for it would then have to be considered, what provision was to be made for the final outflow of the surplus water.

The Act of last Session was, in that respect, imperfect. It provided only for the drainage of limited districts; and the problem still remained, how the water was to find its ultimate escape into the sea? That was, surely, an engineering matter; and until it was successfully accomplished, the evil would only have been transferred from one locality to another. They were in a constant struggle, as it were, with Nature. Bars were always forming at the mouths of rivers, and estuaries filling up; and unless a remedy were provided those evils would go on augmenting. It was not for him to suggest what the remedy should be; he only desired to urge the importance of some combined action, to consider and advise what was best to be done, and to suggest whether some general and comprehensive scheme could not be devised, probably with the co-operation of the Government (for the question, as he had said, was a national one), for arterial drainage. It was a subject than which none could more worthily occupy the attention of a scientific body like that which he had the honour of addressing.

Mr. MALLET would not have offered any remarks on this subject, but that he had had an opportunity of becoming acquainted with what had been done in arterial drainage in Ireland, where such operations had been more extensive than in any other portion of the United Kingdom. He agreed with Mr. Bidder, that the experiments now in question rested on too narrow a basis to be trusted as the certain support of the large conclusions that had been drawn from them; but during the discussion he had not heard any allusion made to very valuable information already before the public, deduced from the great arterial operations which had been executed in Ireland, and of which some portion might be found in the Transactions of the Institution of Civil Engineers of Ireland. Three important Papers had been read on this subject by Engineers who were engaged in the main drainage operations under the control of Mr. Wm. F. Mulvany, C. E., the Commissioner of Drainage, and a member of the Board of Public Works in Ireland. The last of those Papers, by Mr. Betagh, was, he thought, the most important communication on the subject that had appeared. It was, however, to be remarked that all these Papers were deficient in one most important element, namely, none of them gave the mean slopes of the catchments, from which the deductions as to proportion of rainfall and discharge were based, and without which all such deductions were of little general value. Mr. Mulvany, the Drainage Commissioner, was so fully impressed with the importance of this fact, that ten years ago he prepared a set of tables, to be filled up by observations made by his district

engineers. Those tables had been filled up for an immense extent of country in Ireland, and no doubt they still existed in the archives of the Board of Works in Ireland, although they had not as yet been published. They contained a mass of information of a very valuable character, which it might be worthy the attention of the Council of the Institution to endeavour to have made accessible generally.

In the first Paper he had alluded to it appeared, that in certain catchments in the county of Mayo during ten months, the discharge of water was more than the rainfall during the same period—that actually more water came off the land than had fallen upon it, which at first sight might appear to involve a serious error; but no doubt the land was previously more than saturated, and was like a vast sponge giving out water slowly. On the river Glyde, passing the town of Ardee, before the main channels were opened by arterial drainage, it took a fortnight, or three weeks before a rainfall of storm water producing flood came down a distance of about twenty miles. That river meandered, like some parts of the Trent and the Ouse, over a vast tract of rich meadow land, encumbered with vegetation and bulrushes, which slowly let down the water. After the main channels were opened, the flood water came down the same distance within forty-eight hours.

As regarded the proportion between rainfall and discharge, he did not think that evaporation came much in question, unless the main arterial channels were thus seriously obstructed; if they were as free as they ought to be, there was not time for evaporation to come into play, so as materially to affect the result. More than 300,000 acres of land in Ireland had been brought under arterial drainage operations and had been thus improved; and it was the opinion of the best meteorologists in Ireland that these operations had already exercised a sensibly beneficial effect on the climate of that country. Ireland was to England the great sponge, as it were, for the absorption of the precipitated evaporation of the Atlantic waters; and it was not inconceivable that if the climate of Ireland was improved by the precipitated waters being thus more rapidly carried off, the effect ultimately might be that less rain would fall in England, and the climate of the latter might in some portions, especially along its eastern shores, become too dry.

The mean declivity of the surface of any large catchment was one most important element in determining the size of the channels for carrying off the arterial waters. The section of every stream in the world was a curve of the parabolic, or perhaps logarithmic order. Such was the section of the great historic rivers, as the Nile and the Ganges, the influence of which on climate and agriculture had engaged the attention of the oldest

peoples in the world, and even moulded their theologies, or superstitions. The section always presented a hollow curve, rapidly increasing in eccentricity as it rose into the higher regions towards the sources; and the same sort of section applied to the smallest brook. The result of inquiries in Ireland was to show, that the rate at which the water ran off per acre per minute was greater in the smaller catchments than in the larger. The explanation of this fact, which he was not aware had before been given, was this, that small catchments were those of the greatest mean declivity of surface, and so they delivered off fastest. One of the most important collections of data, as to proportion of rainfall and discharge that existed, was to be found in the Blue Book of the Lords' Committee on Irish Arterial Drainage, of 1852. In that Report a Table was given of the rainfall and discharge for nearly forty large districts, some having a catchment of more than half a million of acres, others a very small one; but it was to be regretted that the average declivity was not given for any one of them. That element might still, however, be supplied, for those who had read the investigations of Humboldt, for determining the mean elevation of continents above the ocean, would see that the hypsometrical method employed by him for that purpose was capable of being applied also to this, and, aided by the Ordnance maps, it was possible to obtain the mean slope for any given catchment.

Mr. ROGERS FIELD said, one important point seemed to have been quite lost sight of, the fundamental difference between free soils and clay soils. Most of the observations which had been made applied only to clay soils, which were drained by close parallel drainage, and not to free soils drained by wide 'occasional' drainage. The wetness of clay soils proceeded only from the rain which fell upon the surface of the land, and consequently on them there could not be a greater amount of evaporation than rainfall. In free soils the case was different. There was then not only the wetness caused by the rain which fell immediately on the surface of the land, but that which was caused by the 'water of pressure' from adjoining higher lands percolating to the lower lands, and keeping them in a constant state of saturation. Mr. Bidder had said, that Mr. Charnock's experiments only showed the evaporative power of the atmosphere, not the actual amount of evaporation from the soil, as there would often be no water in the soil to be evaporated. This might be true as regarded clay soils, but it was certainly not true as regarded constantly-saturated free soils. In the latter case the atmosphere could fully exercise its evaporative power, as the water percolating from the higher lands would constantly supply the place of that removed by evaporation. To follow up the illustration, he might say that saturated free soils were in a similar condition to a road kept constantly wet by the

leakage of a water-main beneath its surface, in which case evaporation would evidently have full play, though the surface of the road might never be watered. Therefore he contended, that in the case of saturated free soils, Mr. Charnock's experiments were strictly applicable. Those experiments showed, that the evaporation from soil maintained in saturation was 33 inches per annum, whereas that from drained land was only 20 inches; making a difference of 13 inches of evaporation saved by drainage. If there was any truth at all in these figures, the increase of supply to rivers from the drainage of constantly-saturated free soils must be very considerable. The next question was, did free soils exist to any large extent in this continuous state of saturation? There was no drainage where he had been engaged, in which there was not some land of this description. He would give an instance on a small scale that had lately come under his own observation. On an estate near Chester, which the General Land Drainage and Improvement Company were draining, there was a small field of 6 or 8 acres, consisting for the most part of clay, the outlet of which had run continuously during summer and winter. Before this field was drained, there was a large boggy spot in the middle of it, which was constantly wet, but with no surface overflow. On draining the field, it was found that the part consisted of porous soil, through which water was continually oozing from below. When the drains were cut the water went into them, and was discharged at the outlet, instead of rising to the surface and being dispersed by evaporation, and the result was a continuous flow from the outlet during summer and winter. The effect of the drainage there was, therefore, clearly to rescue water from evaporation, and thereby to create a perennial spring; and similar cases were of constant occurrence on all low lands.

Again, as regarded the effects of drainage upon floods, free soils differed very considerably from clays. Floods were caused by heavy falls of rain being rapidly discharged into the rivers. Now, on land in its natural condition this discharge was not so rapid when the rain had to percolate through the soil, before reaching the rivers, as when it flowed directly into them over the surface of the ground: this was shown by the fact, that rivers which derived their supply to a large extent from water of percolation, or springs, were not so much subject to floods, as those which derived their supply from surface overflow. Thus, for example, rivers in chalk districts which were largely fed by springs, were more uniform in their flow than those in clay districts. This had been strikingly shown by Mr. Homersham, in his comparison of the waterways of bridges with drainage grounds of the London clay formation and the chalk formation respectively. His measurements of eighteen different bridges

showed that, for equal drainage areas, the waterway in clay districts was from three to ten times that in chalk districts, and moreover, that the bridges in the former districts were often filled with flood water, whilst those in the latter were very rarely if ever filled. On the other hand, the summer flow of rivers in chalk districts was considerably greater in proportion to the drainage area than that of rivers in clay districts.[1]

Now, the effect of the occasional drainage of wet free soils was clearly to reduce irregular surface overflow, and to substitute a more uniform discharge by percolation, as in chalk districts, and, consequently, its tendency must be to diminish floods, and to render the flow of the rivers more regular. The drainage of clays also tended to reduce surface overflow ; but in them, partly on account of the large number of drains required, the discharge substituted was much more rapid and irregular than in free soils drained by a few skilfully-placed drains. Thus in clays heavy rains were immediately followed by a greatly increased flow from the drains. In free soils, on the contrary, sudden downfalls of rain did not much increase the flow. The water simply rose in the ground, which thus became, as it were, a reservoir, storing sudden downfalls of rain, and afterwards allowing them to be discharged gradually.

The Hinxworth experiments showed this equalizing action of the free soils very clearly. At the beginning of October the depth of the water beneath the surface of the land, as shown by the test holes, was 5 feet 4 inches. The water level then gradually rose, in consequence of frequent rains, and on December 12th it was 4 feet 1 inch from the surface. On December 13th there was a fall of nearly half an inch of rain, which raised the water to within 2 feet 11 inches of the surface. This constant rising of the water level showed that hitherto water was being stored in the soil. After this, however, there was hardly any rain for the rest of the month, the water level began to fall, and the soil to discharge what had been stored in it ; and the consequence was, that in December there was more water discharged from the outlet No. 7 than the rainfall. Then the water began to rise again in consequence of more rain, and on January 12th it reached its maximum height, only 1 foot 11 inches from the surface. After this the water level gradually fell, with the exception of a few slight fluctuations, and at the end of February it was 4 feet 4 inches beneath the surface, or 2 feet 5 inches lower than on January 12th. A large quantity of the water that had been stored was thus set free, causing such an increase of flow, that, whereas the rainfall during February was only 4,343 gallons per acre, the discharge from

[1] *Vide* Beardmore's Hydraulic Tables, p. 31.

outlet No. 7 was 27,360 gallons, or more than six times the rainfall.

He, therefore, thought it was evident, that free soils, when properly drained by a few occasional drains, would tend to equalize the discharge of the rainfall, and consequently to make the flow of the rivers more regular.

Mr. JAMES BRUNLEES was of opinion, that draining was not generally so well understood as it ought to be, considering that sound views of it were entertained more than two centuries ago. In 1652, in a treatise on draining by Captain Walter Blithe, it was said, "superfluous and venomous water, which lyeth in the earth and much occasioneth bogginesse, mirinesse, rushes, flags, and other filth, is indeed the chief cause of barenesse in any land of this nature * * * Draining is an excellent and chiefest means for their inducement; and for the depth of such draynes, I cannot possibly bound, because I have not time and opportunity to take in all circumstances," * * * and again, "yea, suppose this corruption that feeds and nourisheth the rush, or flag should lie a yard, or four feet deep, to the bottome of it thou must goe, if ever thou wilt drain it to purpose. To the bottome where the spewing spring lyeth thou must goe, and one spade's depth, or graft beneath, how deep soever it be, if thou wilt drain thy land to purpose. I am forced to use repetitions of some things, because of the suitablenesse of the things to which they are applied; as also because of the slownesse of people's apprehension of them, as appears by the non-practice of them, the which wherever you see draining and trenching you shall rarely find few or none of them wrought to the bottome." These were the common-sense views of draining two centuries ago, and were they acted upon now, each kind of soil would be drained in such a way and at such a depth as would meet its peculiar requirements, and ineffective drainage would be unknown. It had been stated that in the fens, more especially in peaty soils, a depth of 30 inches was found to afford sufficient drainage. To show that this statement was incorrect, he would draw attention to the fact, that in fen lands where the material had been thrown into mounds alongside the ditches, there was found in these mounds the most luxuriant vegetation, and the cause of this was evidently that the roots of the plants were farther removed from the cold sour soil.

It was true that there had been instances of peaty and fen lands having suffered during parching and protracted dry weather, in consequence of their being so loose that capillary attraction failed to raise the water to the roots of the plants; but, even though this might occasionally be so, he would still say with Blithe, drain deep enough to prevent the land from being soured by stagnant water in wet seasons, and for droughts let the ditches be provided

with dams, or sluices to raise the water at pleasure to any required height. The general depth of drain recommended by the late James Smith, of Deanston, was 2 feet 6 inches, but many of his drains had, since his death, been reopened and replaced at depths approaching 4 feet. One member had stated that he had put drains in his land at depths varying from 32 inches to 36 inches, but that little, or no water came from them. The reason was obvious,—like Smith of Deanston, he had put the drains above the level of the water-bearing strata, and hence it was not till after a very heavy fall of rain, when the level of the water was raised in the strata up to the pipes, that they began to discharge.

Part of Mr. Brunlees' early life had been spent in the midst of drainage operations, and he had always been a close observer of the effect on vegetation. He had invariably found, that it mattered not whether at home, on the continent, or under a tropical sun, to secure vegetation there must be either natural, or artificial drainage; but to have vegetation in perfection, there must be deep and ample drainage. He need hardly add, that he fully agreed with Mr. Bailey Denton in recommending draining at 4 feet to 8 feet in depth, for in the porous soils it was essential to be under the soaks and springs, and in the clay and tenacious lands, 4 feet, 8 feet, or more, would not be found too much. Every one accustomed to making, or maintaining railway cuttings in this heavy class of soils must have noticed that, from a small soak, or spring, capillary attraction gradually extended the moisture until it caused a large slip. The same operation went on in underground drainage; the water was diffused by capillary attraction to feed the roots of the plants, and hence the level of the stagnant water would be practically too low.

The outfalls of rivers were differently affected by draining. He had no doubt of the correctness of what was said in reference to the river Thames remaining longer in flood at present than it did when the lands were but partially drained; for, where the lands had been thoroughly drained and became saturated by continuous rain, the drains would pass off the water more freely, and thus augment the volume of the river. The same effect would be produced in every river having a low rate of fall, like the Thames; it was, therefore, only in rivers of that class that attention to the outfall was required. Taking, as an opposite instance, the river Tweed, which had a rapid fall, and passed through a district which in general had been thoroughly drained, the floods were not anything like so high as they were twenty-five to thirty years ago, but they both rose and fell more rapidly than they did formerly. There were two important features noticeable in that river; the first was that since the general introduction of drainage, from the water having to percolate into the drains, the surface soil was not

washed away from the land into the river; and, second, and consequent on the first, the river, during floods, was now less charged with mud, and hence there was less deposit carried to the river's mouth to form bars and impediments to the shipping.

Mr. BAILEY DENTON, in replying upon the discussion, said, he did not feel surprised that a Paper which had cost him so much consideration, and he might say twenty years' collection of facts to support its conclusions, should have received so little attention to its details as this had done. He did not say that in the way of reproof, or regret. It was quite impossible that members could collect all the details therein set forth. He did, however, feel astonished at some of the observations which had fallen from Mr. Bidder. That gentleman, when President of the Institution, had asked him to present a Paper, which should contain the results, not of a single experiment, but of his experience of drainage for years; and when he found Mr. Bidder, with a manner so potent, expressing an opinion that the mode of measuring was doubtful, he could not resist the assertion that, having paid much attention to the single object of drainage, and having made it his business, for some years past, to collect results founded on the most perfect and accurate observations, conducted in various ways, and involving different modes of measurement, he knew no more simple and accurate mode of measuring the discharge of water from drains, of the size and character here referred to, than the method adopted and already explained. He might quote the evidence of Mr. Clutterbuck, who having witnessed these experiments, had written,—"I was more than once on the spot, and, in many instances, insisted upon the outfalls being re-gauged in my presence, in order to verify results for which I was not prepared." He thought there could be no reasonable doubts as to the accuracy of these measurements.

It was to be remarked, that the Hinxworth experiments were not given as exhibiting the quantitive discharge from all drained lands; for in various localities, there would be different quantities of rainfall and discharge. He had never offered them as exemplifying more than the relative action of, and discharge from, the two characteristic soils,—the clays and the free soils. He had experiments now going on in fourteen, or fifteen different places in England, all giving different quantities to these, though consistent with them in the relative deductions to be drawn from the draining of the two species of soil. His Paper, at any rate, had satisfied one particular point, and that was the necessity of attending to the question of "arterial" in relation to "under" drainage, which for the present was all he aimed at. Every one had concurred in the statement, that, at certain periods,

the discharge from the upland drainage already affected, and would continue more and more to affect the rivers.

Some observations had been made on the extent of the area upon which these experiments had been carried on. Mr. Bidder had referred to some experiments of his own, but he had not given the details in that tangible way that would enable a comparison to be made with the statements in the Paper. In fact, Mr. Bidder had stated, if he understood rightly, that the under-drainage at Mitcham discharged no water at all. The experiments before the Institution, small as they might be, had extended over 100 acres, which he believed was the largest area ever experimented upon. Now, most of the experiments, to which reference had been made, were restricted to superficial areas of ten and twelve inches square. Mr. Dickenson's experiments were made on twelve square inches of surface; Dr. Dalton's were on ten inches, and Mr. Charnock's on twelve inches square. He did not mean to imply that they were inaccurate, because they were confined in extent. He had more respect for multiplicity than breadth of experiments. Liebig had said, "Science could never be wrong;" and it was by the repetition of experiments that facts could be ascertained and science founded.

He had three objects in bringing forward this Paper. The first was to obey Mr. Bidder's presidential request; the second was to show the Institution that there was an object unattended to, which ought to receive their attention, and which, as Mr. Lloyd had truly said, must come sooner, or later upon the country, and force itself upon the attention of Engineers. If he wanted any eulogium on his efforts in the matter, it would be found in the remarks of Mr. Hawksley, who, in his eagerness to protect the miller, had shown that almost every Engineer would be called into requisition to defend water rights. In the third plan he was personally anxious, that the engineering view of under-drainage should receive the attention of the Institution, although, perhaps, an object foreign to many of its members. Millions were being expended in perfect ignorance of true science, and with a total disregard of those principles which Engineers would recognise. The mere 'gridiron' of drains, represented by the lines on a map of a clay soil, to which they were applicable and appropriate, was not science. Anybody could rule parallel lines on paper and set them out on land; but if they turned to the wet free soils, the extent of which in Great Britain was within a trifle equal to that of the clays, it would be found that in that case science was really required. They had not in such soils to multiply drains to overcome excessive retentiveness; but they had to reduce the water level through percolative matter and to let off, carefully and gradually, that rain which fell upon the surface, and

that water which gravitated through adjacent land into such soils; not to extract it too freely, but to remove the evil of stagnation, and to discharge the water into the rivers, with as little disturbance to the arterial system as possible; not to 'gridiron' each field as a separate work, but to regard each valley, or area of saturated free soil, as subject to a system of drainage, capable of both overcoming stagnation and of increasing the perennial water supply. It was not possible to remove surplus water from clays too quickly, but it was quite possible to remove it too rapidly from free soils; in fact, the more gradual the action of drainage, so long as the water was kept moving, the better for that species of land, and the less derangement of the arterial system would be the consequence. This was a point which must some day receive attention from the Engineers of Great Britain, and have its due influence in the mode of under-draining itself. He said this from a conviction, that the absence of such reflections was hurrying the country into a state of confusion, becoming worse confounded every day; and it would explain, too, the over-draining of certain meadow land, of which so much was said. It was hardly to be expected otherwise, when it was remembered that, from a sense of economy, the landed interest generally left the control of drainage works on their estates in the hands of bailiffs and superior farm-labourers, and dignified the operations by calling them "Government drainage on scientific principles." It seemed almost ridiculous, when science was so deservedly paramount, that in land drainage, an art essentially dependent on engineering and geological data, a parallel ruler should be the guide in all soils and all surfaces. He must refrain from replying seriatim to the observations of the several speakers, although he could say a great deal upon each; but there were a few words which fell from Mr. Gibbs which called for special remark. That gentleman had said that, if they drained too deep, capillary attraction was weakened; and, if too shallow, the air would not penetrate. He begged to join issue. If under-draining was adequately deep, it reduced evaporation, by lowering the water-bed beyond its direct influence, and he had observed that capillary action, when it was uninfluenced by evaporation, was greater, the deeper the under-drains were placed in the ground, arising from the fact that the interstitial spaces were smaller. If a soil constantly moistened by subwater, by capillary action, or otherwise, was subject to full evaporation, it was chilled, and the nearer a soil approached a state of saturation, and the nearer the water-bed to the surface, the more it evaporated and the colder it was. The amount of moisture, too, seized by the soil, permeated by the atmosphere, was necessarily greater in proportion to the depth of soil penetrated.

Some remarks had been made as to the necessary depth of

drainage. That was truly an agricultural detail, and he so recognised it; but, if time permitted, he could show that it was also an engineering question, particularly in dealing with free soils saturated by rain and lateral pressure. Reference had been made to maintaining the water level in peat lands, at from 2 feet to 2 feet 6 inches, as being necessary for the maintenance of the peat in a state of fertility. He could assure the Institution that his experience was directly opposed to that statement. Peat land was consolidated and its fertility was enhanced by deep under-draining. He had been consulted in Holland with a view of introducing under-drainage there, and he might add, that under-drainage in the Fens, 4 and 5 feet deep, was extending every day. Referring the Institution to the quotation from Judge French which he had given in the Paper, he was willing to leave the matter there. But he might be allowed to quote an observation of Lord Palmerston on this subject which had made an impression upon him. When speaking to his Lordship on sub-irrigating peat lands,—*i. e.*, letting water into the land as Fen men did into their ditches,—his Lordship said, "You may do it if you like, but I do not think well of it. A good gardener of the present day never waters his plants from the saucer, as in olden time, but invariably from the surface of the pot, and discards the saucer." In the same way the drainer ought to keep the water level beyond the reach of active evaporation, and to look to aëration and capillary attraction to maintain, with occasional rain, the necessary moisture.

As there were two characteristic kinds of soil, the clay and the free soils, so there were two sorts of wetness,—the wetness from rainfall, and the wetness of saturation, maintained by pressure from surrounding land. So, also, there were two periods and characters of discharge, one, the intermittent, which got rid of the redundant rainfall which found its way from the drains in the clays; and the other, the constant, or perennial discharge, which resulted from under-draining the saturated free soils. The effect of draining the clays, as had been generally admitted, was to throw down into the valleys immense quantities of water, during the discharging period, which by the Hinxworth Tables was shown to last from October to April. This intermittent excess, which affected the rivers, was at the service of engineers, if it was properly stored and applied where wanted; and the observations of Sir John Rennie on this point agreed with those which Mr. Denton had written twenty years ago, in a Paper which was in the library of the Institution, and which dealt with the "application of drainage water!" [1] The effect of drying the saturated free soils of the country would

[1] *Vide* "The Question what can now be done for British Agriculture? &c." By J. B. Denton. Tract 8vo. London, 1842.

be to improve,—that was to increase,—the perennial supply of water to the rivers, by withdrawing from the atmosphere that which the drains discharged in the summer months. He commended that point seriously to the attention of the members. His views were not at present generally concurred in, but he looked forward to a time when they would be so. Formerly he held the opinion expressed by Mr. Lloyd, that the effect of under-draining must be to increase the drought of summer; he now withdrew that opinion, on the simple grounds, which his observations and experience had confirmed, that as no water could be discharged from any drains, until the soil was filled up to the level of the drains, the subterranean supply could not be diminished, and that whatever water was rescued from the atmosphere was a gain to the rivers during the summer.

He was now obliged to close his observations, and he left the subject in a way he did not like to leave it; he felt it had not yet been understood, and that few had followed the Paper throughout. Recurring to the disputed question, as to increasing the perennial supply, he held in his hand a letter from Lord Palmerston, written on the day on which the decision upon the American war was expected to be known in England. It was a letter of no less than six and a half pages; and it was a most interesting fact that his Lordship, at such a momentous time, should write a long letter of that sort, going as fully into the subject as any Engineer could do, and drawing very different deductions from those he had heard in the course of this discussion, and which were popular in the country:—

(Copy.)

"94 Piccadilly, *6th January*, 1862.

"My dear Sir,

"I have received your letter of to-day. The question to which it relates seems to me to be as clear and as simple as anything can be. It is demonstrable that under-draining must render more dry the atmosphere of the lands drained; and, it is equally plain, that it cannot materially, if at all, diminish the supply of water to any river that flows through such lands. Undrained land is like a sponge, it is saturated with the moisture which, by capillary attraction, it draws up from below, and, by the moisture which, in certain conditions, such as sea fogs, it imbibes from the atmosphere, and with the water which falls in the shape of rain or snow. The moisture thus held by this spongy upper stratum of the land, is got rid of mainly by evaporation into the atmosphere in contact with such land, and the quantity of water with which that atmosphere is then charged is, in some cases, very considerable, and, being much greater than the air can hold in solution, it is precipitated in the shape of mists and fogs to the detriment of the health of the inhabitants of the district. The effect of sufficient under-draining is to convert four or five or six feet of the upper crust of the land from the condition of a sponge to that of dry earth. That thickness of crust no longer draws moisture from below

by capillary attraction,[1] and the water which falls upon it as rain or snow, or which is deposited upon it by sea fogs, instead of rising into the atmosphere by slow evaporation, finds its way rapidly into the drains, and is carried off by them. The soil will however, always, by its retentive nature, keep to itself moisture enough to supply the wants of vegetable roots. The good effects then of draining upon the atmosphere of the district drained are demonstrable in theory, and anybody who, like me, has had drained a large extent of land, which before had been very wet, will have amply experienced those good effects in practice. The improvement in the atmosphere of that part of the valley of the Test, which extends from a mile above Romsey to two miles or more below it, is most striking and satisfactory, and is entirely owing to the drainage works which have been executed within those limits. But, then, as to the effect of under-draining upon the supply of water to rivers. Rivers are supplied with water by rivulets which flow into them, and by water which rises from springs in their beds as they flow along. The rivulets will probably be increased in volume by draining works, because they will be made the outfalls for the drainage of land on higher elevations. Then, as to the water, which was before contained in the four or five upper feet of the land through which the river flows,—that water, instead of being evaporated into the atmosphere, is carried along the under-drain, and is delivered into the river at the earliest point at which the descending level of the river will give a sufficient outfall; and supposing the depth of the drain to be five or six feet, in a river of average rapidity of current, the drained water may be discharged into the river at no very great distance from the beginning of the system of drains. Then, as to the feeding springs which rise up in the beds of rivers, the only water that is withdrawn from them is that which would have been contained in the four or five feet of the upper surface of adjoining lands,—and I have already shown that, as regards such water, the river is a gainer and not a loser by the drainage. All the water in the soil below four or five feet from the upper surface of the land will as before find its way in springs to the beds of the rivers, without being in any way diverted from its course by the drainage of the upper surface. That this has been the case with the Test, I can assert by experience, for the volume of its water has not been in the slightest degree affected by the drainage works in adjoining lands. It has so happened that the river has been much fuller of water during the last two years than it had been for several years before; but that was owing to causes quite unconnected with the drainage works.

"My dear Sir,

"Yours faithfully,

(Signed) "PALMERSTON.

"*B. Denton, Esq.*"

This letter of Lord Palmerston's fully supported the opinions which Mr. Bailey Denton had set forth, and had pressed so earnestly on the Institution, viz., that, by draining the valley lands, that were in a continual state of saturation, an amount of water was saved from evaporation during summer, which must go to increase the perennial supply of the rivers.

Mr. Denton handed in the following tabular statement to be appended to his reply:—

[1] This expression is subject to modification. See observations in reply to Mr. Gibbs, page 124.—J. B. D.

TABULAR STATEMENT of Experiments at Broadlands, showing the depth to which the water has been lowered by under-drainage, and the fluctuations in the water-level according to the rainfall.

	Depth of Water in Test Holes below surface of Ground.				Rainfall.		
1861.	Minimum Depth during Month.	Circumstances under which Minimum occurred.	Maximum Depth during Month.	Circumstances under which Maximum occurred.	Monthly Rainfall at Southampton.	Monthly Rainfall at Eling.	Number of Days in which Rain fell at Southampton.
	Ft. In.		Ft. In.		Inches.	Inches.	
Feb.	3 0	After 3 days' rain amounting to 0·55 in.	4 1	After 4 days' cessation of rain.	1·52	2·92	10
Mar.	3 5	After 0·55 in. of rain in 1 day.	4 3	After 3 days' cessation of rain.	1·83	2·25	11
Apr.	3 9	At beginning of the month.	4 4	After continued cessation of rain.	0·27	0·39	3
May	4 0	After 0·95 in. of rain in 1 day.	4 5	After continued cessation of rain.	1·39	1·56	4
June	3 7	After 1·000 in. of rain in 1 day.	4 5	At the beginning of the month.	3·29	3·94	13
July	3 7	After 0·87 in. of rain in 2 days.	4 1	After 5 days' cessation of rain.	3·19	4·59	14
Aug.	3 10	Little rain.	4 6	After continued cessation of rain.	0·60	0·60	4
Sept.	4 1	After 0·45 in. in 1 day, preceded by continuous rain.	4 8	After several days' cessation of rain.	3·02	3·15	13
Oct.	4 2	At beginning of the month.	4 7	At end of month never less than 4 ft. 5 in. for 26 days.	0·78	0·77	9
Nov.	3 5	After 1·60 in. of rain in 3 days.	4 7	At beginning of the month.	4·61	3·50	11
Dec.	3 11	After 0·44 in. in 2 days.	4 5	At end of the month.	1·16	2·02	8

The minimum quantity of water discharged by the under-drains during the above period of eleven months was about fifty gallons per minute, and the maximum quantity exceeded ninety gallons per minute, showing the large amount of evaporation there must have been before under-draining, and the saving effected in favour of the river and the mills below.

The drainage at Broadlands had been executed in 1860-1, in conformity with Mr. Denton's report on the Test Valley, 1853, in which the following remarks were made :—

"As the saturated surface of the valley is constantly presented to the action of the sun and wind, and the peat soil is peculiarly susceptible of capillary action, the amount evaporated will be found to exceed on an average of years the proportion from the porous chalk by at least one-half. Whatever, therefore, is the difference between the evaporation from a constantly wet surface, compared with a drained surface, will represent the loss by evaporation to the miller for power and the irrigator for water, and which neither the one nor the other would perhaps imagine, in the valley of the Test, amounted to 750 tons per annum, from every contributing acre of land.

"But this is not the whole of the miller's loss by the present undrained condition of the valley. It is manifest that the proportion of the rainfall which usually filters through a *porous* soil, and gradually finds its way out again at a lower level, in the present state of the land flows over the saturated surface to the sea as soon as it falls when water is necessarily over abundant. This loss might be in a great measure saved by rendering the surface constantly open and absorbent by drainage, and qualifying it to yield up, for the use of the mills, water which would otherwise never find its way into the stream. It may be fairly assumed, that from these two sources of evaporation and overflow, twelve inches of water over the whole surface of the valley are lost in every year."

Mr. HAWKSHAW,—President,—quite agreed with what had been stated with respect to the drainage of land, and its great importance to the prosperity and wealth of the country; so much so, that any information which was brought to bear on it by Civil Engineers and others who devoted their attention to it was of vast consequence to the country. He did not think it necessary to try to preserve the mills, or the mill power as a rule, in the expectation, or on the hypothesis that coal might become so dear, or so scarce as to render it probable that it would be obligatory, some day to return to what was called "water spinning." He thought that would be interfering with the progress of improvement. Wherever mill power was destroyed, of course it should be compensated for. He would not enter into a consideration of the provisions of the new Drainage Act, which had been so frequently referred to in the course of the discussion, because he thought it hardly came within their province as Engineers to do so. Nor had he any reason to doubt the accuracy of Mr. Bailey Denton's figures, as to the discharge of water from the drains, in the experiments which he had brought before the Institution. He had read the Paper,

and had compared those results with what was probable, and he quite conceived he might obtain from land, under certain circumstances, and on such an area as he had operated upon, the quantity of water which he had stated. Of course whether the quantity of water, so discharged by those drains, represented the area of rainfall on the land, was another question. For anything that was known, the quantity of water so discharged might be from a much larger area of rainfall than that which belonged to the extent of land drained. In draining what were called free soils, into which the water came from more distant points, it was possible in 100 acres to get the rainfall of 300 or 400 acres. But Mr. Denton obtained about one-fourth of the rainfall. Some years ago, when it was proposed to sink a well at Watford, it was necessary to go into that question very carefully, and it was found, that under certain circumstances 27 per cent. of rainfall had passed through 3 feet of earth; therefore he did not make these observations with a view of leading to the supposition, that it was correct to take the results which had been given, as a basis on which to argue as to the régime of rivers.

With regard to the important question, to Engineers, as to the effect of land drainage on the régime of rivers, he concurred with many of the speakers, that a larger amount of information was requisite, before it would be safe to generalise on the subject. He must confess, that he had arrived at rather an opposite opinion to that which the Author would lead the meeting to form on that subject. He believed that on certain soils drainage might diminish the quantity of water which passed to the rivers; though he thought there were cases where it might have a contrary effect. But still he was not sure,—admitting what had been stated, and he thought the conclusions were perhaps sound as regarded the particular locality referred to—yet he imagined there were cases where the result might be quite different. For instance, chalk would absorb one-third of its bulk of water. When there were 30 inches of rainfall the chalk would absorb 10 inches. Then taking a soil which did not naturally resemble chalk, but which by draining might have the character of chalk given to it, by adding to its porosity and by draining it, then, instead of the water passing off quickly to the rivers, it would be absorbed, as in the chalk, and it would be given out again by evaporation. He mentioned this as a case where the results might be opposite to those which had been given.

Where drains were put into a free soil, the water was led away quickly instead of having time to saturate the surface; thus evaporation was diminished, and the water was taken away to the streams, and then an addition was made to the quantity of water coming into them. He thought therefore that much more informa-

tion must be obtained before it would be possible to form sound conclusions on that point.

With regard to the question of drainage itself, he did not profess to have sufficient knowledge of it to be able to enter into the details of the depths necessary for the drains, whether they should be 3 feet, or 4 feet. That was a matter which could only be arrived at by practice and experience, and it depended very much on the nature of the locality operated on. He would say in conclusion, that the Institution was much indebted to Mr. Bailey Denton for the Paper, which contained much information, and would be useful to all who were interested in the subject.

December 10, 1861.

GEORGE PARKER BIDDER, President, in the Chair.

BEFORE proceeding with the regular business, the President directed attention to the numerous donations to the library, which had been received during the recess; particularly noticing the series of seven volumes of "Transactions of the North of England Institute of Mining Engineers," through the President of that Institute, Mr. N. Wood, M. Inst. C.E.; the volumes containing the abstracts of "The Principal Lines of Levelling in England and Wales" and in Ireland, from Colonel Sir Henry James, R.E., C.B. (Assoc. Inst. C.E.); "The Quarterly Review," vols. I. to LX., from Mr. J. S. Crossley, M. Inst. C.E.; thirty-five volumes of "Greenwich Observations" and other publications of the Royal Observatory, Greenwich, through Professor Airy, Hon. M. Inst. C.E.; the "Annales des Ponts et Chaussées" from 1843 onwards, through Monsieur Cavalier, Directeur de l'Ecole des Ponts et Chaussées; the "Journal of the Franklin Institute" from 1851 to the present time, from the Institute; a set of the Alphabetical, Chronological, and Subject-matter Indexes of Patents for Inventions, together with the Abridgments of Specifications relating to different subjects, from H. M. Commissioners of Patents, through Mr. Bennet Woodcroft; the series of volumes detailing the Magnetical and Meteorological Observations made at different stations in the British Colonies, through General Sabine, President of the Royal Society; the Publications of the Geological Survey of Great Britain, through Sir Roderick Murchison, Director-General; a Geological Chart of the Austrian Empire ("Geognostische Uiber-