ANTI-MALARIA MEASURES IN MALAYA.

By Major J. H. C. Walker,
Royal Army Medical Corps.

PART I.—HISTORICAL.

The following resolution was passed unanimously at the final session of the Malaria Section of the Congress of the Far Eastern Association of Tropical Medicine, held in Calcutta in December, 1927:—

"As it has been represented that differences of opinion regarding the best method of controlling malaria sometimes cause doubt in the public mind and so may hamper the progress of anti-malaria work, this Congress takes this opportunity to emphasize the fact that there is no single method of malaria control applicable to all conditions and all countries. Nevertheless, they consider that for towns, mines, plantations, large public works and similar aggregations of people, the control of the breeding places of the malaria-carrying specimens of mosquito is a method which should be employed whatever other anti-malaria measures are put into force. Whenever possible the control should be effected by permanent works which eliminate entirely the source of mosquito breeding.

"For wide rural areas, especially those with scanty poverty-stricken populations, the first step in the control of malaria is adequate research so that conditions present may be ascertained as a result of such research. Methods of prevention may here be of great variety and include drainage, flooding, jungle clearing, jungle preservation, bonification, the promotion of agriculture, improvements of housing and the general economic condition, education etc., of the people. The systematic killing of infected adult mosquitoes, screening, the use of anti-malaria drugs and a host of special methods have each also to be considered in their proper application.

"The Congress desires to stress the need, not only of thoroughly trained malaria research officers, but of expert malaria engineers in whatever type of malaria prevention is at stake."

This resolution, it will be seen, insists upon the destruction of mosquito larvae as essential for the control of malaria, and is in effect an approval of the measures of "species sanitation" already so successfully practised in Malaya. The result has been to turn attention to Malaya, and it is thought that a short account of the measures employed there might be of interest.

Malaya may be looked upon as specially favoured, as progress has been practically continuous since the work first started in 1901, twenty-eight years ago.

The control of malaria in India by means of antilarval methods was attempted in 1902 and 1903, but was unfortunately not successful, and in
1909 at a conference held in Bombay it was said that “Mian Mir had demonstrated the futility of antilarval operations” [1].

That this should have happened was unfortunate as, no doubt, it had the effect of preventing research in India along the lines that have since proved so successful in Malaya. At the same time it has, no doubt, created a feeling of suspicion with regard to these measures which it will take time to overcome. That this is so may be judged from the recent account of “Military Hygiene and Pathology in India,” in the journal of the Royal Army Medical Corps [2], which states that because mosquito proofing of barracks at Lahore has been successful in reducing the amount of malaria at that station, “a definite policy, suited to military needs, can now be formulated.” As part of this “definite policy,” “cold storage” and “mosquito proofing of barracks” are given pride of place, whilst anti-mosquito measures are placed sixth and permanent drainage is not, apparently, contemplated under any circumstances, as the only mention made of “drainage” is under the heading of “anti-malaria measures,” i.e., “minor drainage schemes.”

This, in spite of the resolution quoted above which was passed at Calcutta in December, 1927, and in spite of the success of anti-malaria drainage in Malaya.

“Military needs” should not be a sufficient excuse to banish completely all thought of “permanent drainage” for India, nor should the fact that drainage has failed at one station prevent its trial at other stations.

It is realized that there may be strong financial reasons for confining these anti-malaria measures to “military needs”; one and a half lakhs (£11,000) [2] for anti-malaria measures for India in 1926 does not compare very favourably with the $100,000 (about £13,000) allotted for anti-malaria work in the rural area of Singapore for the same period. It is hoped, however, to show later that permanent drainage is cheaper in the long run.

In Malaya, except when opening up new areas, and drainage is in progress, mosquito proofing of houses is looked upon as an admission of failure to control the scourge at its source and it is rarely seen.

It has already been stated that progress has been continuous in Malaya. This is not strictly correct. There were numerous set-backs, but in every case the work was again continued on more or less the same lines, and some new success helped to convince people that the way to tackle malaria was by permanent antilarval measures.

The honour of being first to attempt malaria prevention by permanent drainage belongs to Sir Malcolm Watson who, in 1901, as Dr. Watson, a health officer, decided to try this method at Klang, the chief town of a district in Selangor State, one of the Federated Malay States.

Ample funds were forthcoming and success attended the first efforts at drainage. It might have been easily otherwise, and in this connection Sir Malcolm Watson says: “Although the success was due to a fortunate choice of the method adopted, as it turned out there was a real stroke of
luck, not recognized until some years after. It was this: Had the hills of Klang been higher or had Klang been situated in the main range of hills, instead of being practically an island in the coastal plains, the clearing away of jungle from the hills and the draining of the valleys and swamps would have led to the introduction of a new malaria-carrying anopheles, certainly not less terrible than the one we got rid of by our drainage”[3].

In September, 1901, the new port for the F.M.S., Port Swettenham, was opened and the Government population and the coolies connected with shipping were transferred from Klang to Port Swettenham. Malaria immediately started, and the outbreak became so severe that within two months it was impossible to carry on the work of the port and it had to be closed, the staff and the coolies being returned to Klang. Antilarval measures were immediately commenced. “An area of about 100 acres was bunded, drained and freed from jungle (figs. 1 and 2). All possible mosquito places were oiled freely. Quinine was systematically given to all who would take it, and most did [3]. The result was that at the end of six weeks the port was again in full working order.

The work at Klang took some years to complete, but a certain measure of success was apparent soon after it was commenced and this, together with the success achieved at Port Swettenham, convinced everybody that the work had been started on the right lines. As a result the work of fighting malaria was rapidly extended by the health authorities and by private firms. Ample funds were made available by the F.M.S. Government as occasion demanded, and many further successes were reported. Large sums of money were expended in putting in permanent drainage and subsequent history shows this to have been more than justified.

As the work was extended many new problems presented themselves and were overcome. It took time to discover that a different species of mosquito with different habits carried malaria in the hills, and it took time to discover new methods of dealing with it. “In 1911 subsoil drainage, a method of putting streams underground out of the reach of anopheles, was started on Seafield Estate” [3]. Permanent anti-malaria drainage was started in Singapore and Kuala Lumpur about the same time.

The year 1911 can really be looked upon as the turning-point in anti-malaria work in Malaya; prior to that year there were at times, following failures in other countries, feelings of doubt in the minds of those responsible for these measures, but since then there has been an unbroken series of successes. At first naturally the work was crude, and many refinements and modifications have been and are still being introduced.

During this period of evolution, prior to 1911, many mistakes, some of them costly both in money and lives, were made. Some of the mistakes were due to lack of knowledge of the habits of the mosquitoes and some to lack of knowledge of the exact methods of dealing with breeding places. One of the best examples of both of these mistakes occurred at Kuala Lumpur, the capital of the Federated Malay States. The experience gained
as a result of these mistakes has done much to influence the trend and organization of modern work, and in consequence a detailed account of the happenings at Kuala Lumpur is given. Not only have the experiences at Kuala Lumpur been directly responsible for new methods of anti-malaria work, but the whole of the present organization of this work may be said to have resulted from them.

_Kuala Lumpur._—The town of Kuala Lumpur at the time of these happenings covered an area of about 20 square miles, made up mostly of hills and ravines. The population in 1905 was 38,459, in 1920 it was 67,930. In 1905 most of the Europeans were housed on the hills in the European residential reserve, and prior to 1906 malaria was practically

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**Fig. 1.—Tidal gate and part of Bund.**
unknown amongst the inhabitants of this area. In 1906 a start was made, for various reasons, to clear the bush from many of the swamps and ravines, and drainage was attempted by the Public Works Department. *Malaria then appeared.* In 1907 spot maps showed that a large number of the cases of malaria came from districts in close relation to these cleared areas.

![Image of Earth drain at low tide. Quarantine Station on reclaimed ground in background.](image)

The following abstract from a report by the Health Officer aptly describes the condition of these ravines: “The method of draining valleys below Federal Hill is far from satisfactory, if not entirely wrong, as far as the attainment of the object of preventing breeding grounds for mosquitoes is concerned. The herring-bone system adopted leaves the ground between dry, but the drains themselves are grand breeding places. The drains below the European hospital are lined with stones, and the result is the
formation of small pools. The drains should be on the lines of Klang. Without money for upkeep it is a case of throwing money into swamps" [3].

At Klang contour hill-foot drains were used to intercept the water from the hills.

The situation became so serious that in September, 1907, the British Resident appointed a committee to examine the areas affected and advise methods for their improvement. The committee consisted of a civilian, an engineer, and two medical officers, and in addition the services of the Government entomologist were obtained.

The entomologist, Mr. C. H. Pratt, discovered larvae of anopheles

**Anti-Maculatus Drainage.**

"present in the streams flowing through the cleared portion of the valleys, but not in those parts where the streams remained covered with a thick growth of bushes" [3]. Dr. Fletcher, a member of the committee, confirmed Pratt's discovery, and in a letter to the chairman of the committee he stated: "These facts demonstrated the great danger of clearing jungle, unless it is possible at the same time to convert these streams into regular channels with cleanly-cut sides, preferably of cement or brick" [3].

In 1908 the committee furnished a detailed report and submitted a scheme of drainage to cost 27,585 dollars, and also asked for an annual grant of 2,000 dollars for upkeep.

The findings of the committee were so at variance with the views then existing that little credence was given to the discovery of Pratt and Fletcher.
As a result the sum asked for by the committee was cut down from 27,585 dollars to 10,320 dollars, and nothing was allowed for upkeep.

The work was entrusted to the Public Works Department, who endeavoured to carry out the task without inviting co-operation from either medical officers or entomologist; as their knowledge of mosquitoes was negligible they were unable to check their results. And, in direct opposition to the recommendations of the committee, the valleys were cleared without being sufficiently drained.

Contour hill-foot drains which had been successful at Klang were not employed, although recommended by the Health Officer. Straight drains on the herring-bone system were put in; these drains only dried the ground within a few feet of them, the intervening ground remaining wet. Many

other mistakes were made, and when all the money had been expended the valleys were only half done. But it is probable that even if all the money asked for by the committee had been allotted no improvement would have been noted, as the work completed by the Public Works Department had little or no effect on the mosquitoes. In 1909 the malaria was still as bad as ever. Dr. A. R. Wellington carried out a survey of the ravines and the result confirmed the findings of Pratt and Fletcher—larvae were found easily in the cleared portions, whilst in the jungle-covered portions they were almost absent. The condition of the valleys drained by the Public Works Department was, if possible, worse than before. Dr. Wellington submitted a report showing, with the assistance of spot maps, that an entirely new problem had presented itself. He pointed out that it was

![Fig. 4.—Shallow swampy valley. A. maculatus breeding in seepages along the sides and in the central stream.](image-url)
only necessary to allow the jungle of the ravines to remain to prevent malaria, and also that if the ravines were cleared it was necessary to put the water underground.

In 1910 and 1911 further sums of money were voted and more work was carried out by the Public Works Department, some controlled by entomological observations and some not. On the whole the results were bad and in 1911 malaria was still increasing.

In 1911 the Principal Medical Officer, Federated Malay States, recommended to the Government the appointment of a standing committee, pointing out that in the attempts to control malaria there had been a division of responsibility and lack of thoroughness and that unsuitable methods had been employed.

The Government approved the suggestion, and thus the Malaria Advisory Board came into existence. Under the guidance of this board, which consisted of civilians, medical officers and an engineer, work was carried out during the next two years, and in 1913 the European area was free from malaria and has remained so since. In his report for 1913 the Health Officer of Kuala Lumpur, discussing malaria, said: “The great drop in the death-rate for this disease must be attributed to the extensive drainage operations which were undertaken by the Malaria Advisory Board to get rid of the breeding places of malaria-carrying mosquitoes. Valleys which were teeming with maculatus larvæ are now bone-dry” [3].

The success attending the efforts of the Malaria Advisory Board was so marked that it has been retained ever since and its scope has been extended. In addition there is now an anti-malaria engineer for the F.M.S. who controls and supervises all new schemes, and who from a central position is able to collect and distribute information regarding new methods of prevention. There is also an anti-malaria medical officer who works at the Malaria Research Bureau at Kuala Lumpur with the Government entomologist, and who is also in close touch with the anti-malaria engineer. At smaller stations engineer and medical officers tackle all major anti-malaria problems together.

Up to the end of 1917 the Malaria Advisory Board had expended in Kuala Lumpur alone 183,971 dollars on new work and 59,230 dollars on maintenance. They had put in 65 miles of subsoil piping, 8½ miles of open masonry channels and 12 miles of open earth channels. Since then the work has been almost doubled.

Singapore.—While all this was happening at Kuala Lumpur work was being gradually extended throughout Malaya. In 1911 Singapore suffered severely from malaria and Sir Malcolm Watson was asked to recommend measures to improve the situation. An anti-malaria committee was formed and under its supervision work was started. The effects of the work were noted immediately in the spleen rates of the school children, the results in two of the drained areas being as follows :—
Since this initial success, up to the present time, the work has been extended and the Singapore municipal area is now practically free from malaria. An excellent example of the efficiency of the work is brought out by the malaria figures for British troops stationed in Singapore; since 1925 no cases of malaria have been contracted amongst the troops in Tanglin Barracks. In pre-war years malaria was always present.

Another interesting example can be found in the history of malaria on Blakan Mati, an island in Singapore harbour which is War Department property. During the war, Dr. P. S. Hunter, the Municipal Health Officer, Singapore, was mobilized for duty with the R.A.M.C. and, being stationed for a time at Blakan Mati, he undertook the task of reducing malaria.

In 1915 he submitted his scheme which was approved, and the work was carried out during 1916 and 1917. The success of the work is apparent from the following table showing the admissions for malaria.

The number of troops stationed on the island has varied very little during the period under review; if anything, the garrison has tended to increase.

The reduction in 1913 was due to the evacuation of certain forts in a heavily infected area, the equivalent of "cold storage" [4].

In 1921 intensive efforts were started in the rural area of Singapore to reduce the incidence of malaria, and the spleen rates tabulated below show what remarkable results can be achieved in a short space of time by "species sanitation" [5].

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<th>1914</th>
<th>1915</th>
<th>1916</th>
<th>1917</th>
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<td>1925</td>
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<td>10 (7 directly traceable to new work and jungle cutting)</td>
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<td>1926</td>
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<td>2 (probably contracted outside the island)</td>
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<td>460</td>
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Anti-malaria Measures in Malaya

Many further examples could be given of the remarkable results obtained in Malaya, but this hardly seems necessary in view of the resolution passed at the Congress of the Far Eastern Association which is quoted above.

The foregoing has been briefly an account of the evolution and success of permanent anti-malaria drainage, but whilst this progress was being made much work was being done in other directions, mainly of an anti-larval character. An exception, however, which saved innumerable lives and enabled many miles of country to be opened up, seems worthy of note. During the investigation of malaria on the coastal plains, where malaria is carried by *A. umbrosus*, and where many estates were being opened up, Sir Malcolm Watson noticed that by placing coolie lines in the cleared areas at a distance of half a mile from the uncut jungle the health of the coolies immediately improved and malaria practically disappeared.

Research into the habits of Malayan mosquitoes and preventive measures have been going on continuously. And since the war propaganda has been wide, circulars have been issued in all the languages in use in the country, lectures and demonstrations are continually being arranged, and by means of travelling motor dispensaries many cases of malaria are treated. The result has been the growth of an "anti-malaria mindedness" throughout the country, which is increasing from day to day. No new work is now undertaken without adequate arrangements being simultaneously made for anti-malaria measures, and these whenever possible are of a permanent nature.

The result of all this work has been the opening up of vast tracts of hitherto forbidden land, the saving of thousands of lives and dollars, and of necessity a tremendous improvement in the general economic condition of the country. Millions of dollars have been expended on this work, but they have been returned a hundredfold.

PART II.—ANTI-MOSQUITO MEASURES.

"Species sanitation" is, at present, the keynote of the anti-malaria measures, for with few exceptions the anti-mosquito measures are entirely confined to controlling the breeding of the three mosquitoes which are the chief carriers of malaria in Malaya, the destruction of other mosquitoes being as a rule purely incidental.

Early in the anti-malaria campaign in Malaya, *Anopheles ludlowi*, *A. umbrosus* and *A. maculatus* appeared to stand out as the probable carriers of malaria, and subsequently an extensive study of the habits and distribution of all the known Malayan mosquitoes has confirmed this.

The fact that these three mosquitoes are confined to three more or less distinct zones has done much to help the problem of combating them.

In the mangrove zone which consists of mangrove forest, *A. ludlowi*
flourishes. *A. umbrosus* is also found in this zone and more inland in the coastal zone. *A. maculatus* is practically confined to the inland zone.

There is a considerable amount of overlapping in the distribution of *A. ludlowi* and *A. umbrosus*, but, as good drainage and clearing removes both insects, this does not matter very much. It is fortunate, however, that the distribution of *A. umbrosus*, does not extend into the inland zone, where *A. maculatus* can be controlled by leaving the jungle-covered ravines untouched. When it is necessary to clear them extensive drainage is always undertaken.

The Mangrove Zone.—As already stated, this consists of mangrove forest, and it can be roughly subdivided into two smaller zones. One, nearest the sea, is covered twice daily by the incoming tide and is free from malaria. The other zone, further inland, is covered by the sea at spring tides for a few hours every twenty-nine days. In this zone many breeding places exist owing to the formation of pools by fallen trees and by mounds made by crabs. Immediately following a spring tide the water in these pools is sea water, but tropical rains and seepages quickly reduce the salinity of the water and render it suitable for mosquitoes to breed in. In the virgin state *A. umbrosus* is found in this zone, but if for any reason the jungle is cleared *A. ludlowi* makes its appearance.

When this inner zone is cleared of jungle the work of controlling mosquito breeding in it by temporary measures may be exceptionally difficult, owing to the very great thoroughness necessary to reach all the breeding places, and it is much more satisfactory to employ permanent measures.
Temporary measures consist of completely clearing, levelling, draining and oiling; occasionally it may be possible, by removing obstructions, to admit the sea at every high tide.

Permanent measures consist in clearing and filling, or completely shutting out the sea by means of bunds and by putting in clean open drains in which sluice gates are fixed (figs. 1 and 2).

![Earth drain partially completed with inverts and slabs.](image)

When building these bunds, it is possible by placing the sluice gates at low tide level to reclaim land in the outer zone, and in this way while preventing malaria to add useful land to the area of an estate.

It was work such as this that was undertaken at Port Swettenham in 1902, and which enabled the port to be developed free from malaria.

The Coastal Zone.—This zone may also be subdivided into two zones—the coastal plains, which consist of flat land covered by dense jungle in
which the ground water is permanently above the surface level, and the coastal hills which are low jungle-covered hills lying in an intermediate position between the coastal plain and the inland hills.

In the coastal plain *A. umbrosus* flourishes, whilst it is also present in the coastal hills as long as they are covered with jungle. *A. umbrosus* can be banished from the coastal plains by clearing; if, however, clearing is carried out on the coastal plains *A. umbrosus* is driven out, but *A. maculatus* immediately appears to take its place, as it finds a suitable breeding place in the streams running between the hills. It is thus necessary to be prepared to carry out "anti-maculatus" measures when these hills are cleared.

Many of the original rubber estates in Malaya were situated in this coastal zone, and although the health of their labour forces was excellent on the flat lands following clearing of the jungle, the same could not be said of the hilly portion of their estates, and it was not until 1911, when burying of the streams running between the hills was recommended by Sir Malcom Watson, that the problem was solved.

In both situations while clearing was in progress the coolie lines were placed at least half a mile from the uncut jungle. This had the effect of reducing the malaria to a minimum.

In the plain zone, when the jungle is cleared, it is of course necessary to lower the level of the ground water, and this is done by means of earth drains, the sides of which are kept clean and trimmed. Concrete drains are also used, but in unfrequented rural areas they are not necessary. Levelling of the intermediate areas is necessary to remove any pools that may exist. Oiling is employed as a temporary measure.

*The Inland Zone.*—This zone comprises the main portion of the Malayan Peninsula. It consists of hilly undulating jungle-covered country which runs from the central range of mountains, the backbone of the peninsula, to the coastal hills. In this zone *A. maculatus* reigns supreme, *A. umbrosus* being rarely found and *A. ludlowi* never. But *A. maculatus* is only discovered when sunlight has access to the breeding places.

As has already been stated, in the history of anti-malaria measures at Kuala Lumpur and in the coastal hills, *A. maculatus* was suspected to be the carrier in the ravines from an early date, but it was not finally accepted as such until 1911, when the work of draining these ravines was started in Kuala Lumpur and Singapore, and by Sir Malcolm Watson in the coastal hills. The importance of the observations of Pratt, Fletcher and Wellington that this mosquito did not occur in the ravines until the jungle was cleared was not fully realized until 1913, when it was confirmed by Dr. Strickland. But it is now a well-recognized rule throughout the country not to disturb the jungle unless anti-malaria measures can be undertaken. *A. maculatus* is not confined to the ravines, but appears throughout the country in any clean running water to which sunlight has access. Even the smallest seepage may be responsible for outbreaks of malaria. These seepages may
Anti-malaria Measures in Malaya

occur in the most unlooked-for places, and even in drained areas it is necessary to keep a strict watch, particularly in very dry weather. An interesting example of this is reported by Dr. P. S. Hunter from Singapore. Two small reservoirs had been built by bunding across a ravine; they were fed by water collected in subsoil drains higher up the ravine, the water being led into the reservoirs over a spillway. The floor of the reservoirs was the sloping bottom of the ravine. During a spell of dry weather the level of the water in the reservoirs fell and the floor was thus exposed. In this exposed part numerous springs appeared as small trickles of water. *A. maculatus* was present in these springs. The trouble was overcome by excavation and rough concreting down to the water's edge.

*A. ludlowi* and *A. umbrosus* are now easy to control, but with

*A. maculatus* the situation is more difficult, and it is for this reason that so much time and money have been expended in evolving preventive measures.

With several different authorities carrying out this work certain differences have arisen in its execution, but the principle in all cases has remained the same, i.e., the removal of the breeding places by permanent measures where possible. This is done by controlling all surface water in subsoil drains or concrete surface channels.

In the F.M.S. the whole of the subsoil water is controlled by subsoil pipes, and then led away by large central subsoil pipes or solid concrete channels. Before the work is commenced the land is surveyed and the course of the pipes and the size required are plotted on a map.
Fig. 8.—F.M.S. system.

Fig. 9.—Section in area A-D.

Fig. 10.—Subsoil pipe.
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In the Straits Settlements, with the exception of the municipal area of Singapore, similar work is carried out, but, instead of a solid channel, the central drain is made of concrete sections three feet long, which are laid about one-half of an inch apart (figs. 3 and 12).

In the Singapore municipal area deep central drains are used to carry off the water as far as possible, and subsoil pipes are only used to tap water not caught by these (fig. 11).

The method employed is to dig deep earth drains down the centre of the area to be drained and to observe the effect over a period of about three months, deepening further if necessary. At the end of this period the central drain, if found adequate, is completed by the use of concrete sections, as described in the Singapore rural area.

In all cases it is necessary to legislate for wet weather, and this is particularly so in the type of the work carried out in the Singapore municipal area.

The F.M.S. system of drainage is shown in figs. 8 and 9, which represents a rough contour map of a valley with steep sides and a flat swampy bottom. The dotted lines A to B, A to C, represent "subsoil contour drains." These are laid at varying distances up the hillside and should be deep enough to catch all water coming down the hillside before it can find its way on to the surface of the valley. The drains are laid in straight lines and inspection eyes and relief drains are put in about every fifty yards, or oftener if necessary. Drains "chain-dotted" are relief drains; these are not primarily intended to catch water, all water except deep springs being caught by the contour drains A to B, A to C. Special subsoil drains are employed when necessary to control deep springs. From A to D the central relief drain is a subsoil pipe, but from D to E it is an open concrete channel cast in situ with turfed banks above it.

The central drains in this system need only be deep enough to carry off the water from the contour drains. In the deep central drain system, used in the Singapore municipal area, however, the depth is a matter of primary importance in order to bring the subsoil water level as low as possible and avoid the necessity of laying subsoil pipes. This is particularly so in flat areas.

This drawing shows a cross-section of a similar valley to that shown in fig. 8, and demonstrates the effect of deepening the central drain on the "hydraulic gradient." The lowest drain dries up the valley as far as Y and does away with the seepage at A, which was unaffected by shallower drains.
The deeper the drain the larger the area drained; the nature of the soil, of course, causes modifications and subsoil pipes are employed when necessary.

These earth drains are observed for a time and, when found to be satisfactory, are completed in the same manner as in the Singapore rural area (fig. 12). The advantages claimed for this method are that it saves expense, labour and upkeep. It is necessary, however, to keep a strict watch on the drained area and to be prepared to put in subsoil pipes should seepages appear.

Figure 12 shows in longitudinal and cross-section the method employed in the Singapore area.

The system is a combination of the two methods already described. The subsoil water is mainly controlled by subsoil pipes, but the central drain, while laid at a greater depth than in the F.M.S., is not so deep as in the municipal area of Singapore. By leaving gaps between the sections of pipe forming the drain water finds its way into it from below. The drain consists of three areas: (a) earth sides, grassed; (b) concrete slabs, two feet square; (c) half sections of spun concrete pipes, three feet long, manufactured by the Hume Pipe Company (fig. 3).

In making these drains an earth drain is dug down the centre of the area to be drained, and then the half sections of pipes "inverts" are laid about half an inch apart. They are cemented together in their upper third only and water can thus enter the drain from below; sometimes a layer of broken brick or small stones is placed underneath; this depends on the soil. Area B consists of concrete slabs, two feet square, cemented together and to the top of the inverts. These always have a layer of broken brick or stone behind them. If this is not done water may collect there and gradually force its way over the top, forming dangerous seepages. The broken brick allows it to make its way down and find its way into the drain from below. Area A is the top of the original earth drain on which sods have been laid. It is found that once the sods have "taken" the area can withstand any rush of storm water that may occur. Subsoil pipes are laid as in the F.M.S., and relief drains join the central drain at intervals.

"Weep-holes" are now rarely employed in these central drains, as
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A. maculatus has occasionally been found breeding in them. If they are necessary great care must be taken to prevent pockets forming in the earth behind the slabs.

Subsoil Drains (fig. 10).—These are made with ordinary baked clay agricultural pipes. They vary in size from three inches in diameter to one foot. If bigger pipes than this are required spun concrete pipes are generally used. Before the pipes are accepted from the makers a very close inspection is carried out to exclude pipes that are at all misshapen, as experience has shown that distorted pipes very often collapse and cause blockage of the drains. The pipes are laid about one inch apart, and a minimum depth of five feet is aimed at to prevent damage by roots. Until recent years the junction of the pipes was left uncovered, but experience has shown that silting up occasionally occurs through soil entering the drains from above. It is usual now to cover the upper third of the gap between the pipes; this prevents soil entering the drain and allows the water to enter from below. Various substances are used for covering the junctions—palm leaves, broken pipes, clay, etc. Inspection eyes are placed at intervals of about fifty yards, and at all junctions or bends. These inspection eyes are formed by placing subsoil pipes end to end vertically and covering the top with a concrete slab.

Maintenance.—This is just as important as the primary drainage, and it is necessary to have ample funds available in order to carry out repairs as they become necessary, to add new drains if required, and to allow of frequent inspection of drained areas and cleansing of all open channels.

Inspection of all drained areas is carried out at least once a month. In Kuala Lumpur it is done weekly. All open channels must be kept free of weeds, particularly in dry weather, as A. maculatus will breed in concrete channels if weeds are allowed to grow in them and heavy rainfall does not flush them.

The grass in all drained areas must be kept short, for if this is not done "lalang" grows rapidly, and its roots cause blocking of the subsoil drains; for the same reason trees and jungle are not allowed within twenty feet of drained areas.

While the harnessing of the subsoil water has been in progress many ingenious methods of utilizing it for the community have been evolved.

Subsoil water is used to provide drinking and washing water, to supply dhobie ghats, and to flush latrines, etc.

Conclusion.—In a brief account such as this, adequately to describe the work that has been done in combating malaria in Malaya is impossible, and no mention has been made at all of the excellent rural sanitation which is to a large extent dependent on this work. To those who would know more, Sir Malcolm Watson's book, "The Prevention of Malaria in the Federated Malay States," from which I have quoted freely, is recommended. Much valuable information is also to be found in "The Engineer and the Prevention of Malaria," by Henry Home. One point more than any
J. H. C. Walker

UNSUCCESSFUL DRAINAGE AT LYMREN, HONG KONG.

Fig. 13.—Solid concrete drains with weepholes. Herring-bone system. A. maculatus was found breeding both in the drains and all round them. A single deep central drain would have dried this area almost completely.

Fig. 14.—Further attempts at anti-maculatus drainage with solid concrete drains. Unsuccessful. A single contour drain would have dried this area.
other which needs emphasizing is the necessity of employing engineers on anti-malarial work, and of having between these engineers and the anti-malaria medical officers the closest co-operation.

At Lymeun Fort, in Hong Kong, an extensive system of drainage intended to be "anti-malarial" has been made in the past, but owing to the nature of the drains, i.e., solid concrete on the herring-bone system, they have made matters worse by holding back the subsoil water and forcing it on to the surface. *A. maculatus* was found breeding extensively all over the drained area and in the drains (fig. 13). Had the results of the drainage been checked by an entomologist or by an engineer officer with a knowledge of the habits of *A. maculatus*, the situation noted would never have arisen. In addition to co-operating with the anti-malaria medical officers, it is imperative that the engineers should realize that unconsciously they may, in the course of their work, be forming breeding places. If the engineers take the anti-malaria medical officers into their confidence endless work and anxiety may be saved.

Continuity of supervision is another essential factor for success, and in consequence in the Army, where moves may be frequent, the formation of anti-malaria committees is important, both for the supervision of work and the preservation of records.

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REFERENCES.


