COASTAL RIVER IMPROVEMENT IN RELATION TO LAND UTILISATION IN NEW SOUTH WALES.

A STUDY OF AGRICULTURAL CONDITIONS AND POSSIBILITIES OF SUPPLEMENTARY IRRIGATION IN THE WARRELL CREEK DISTRICT OF THE NORTH COAST.

BY

ALISON M. KINGSLAND and J. RUTHERFORD,

Economics Research Officers.

1. INTRODUCTION.

An examination has recently been completed of the lower Warrell Creek district which lies approximately three miles to the south of the town of Macksville. As one phase of the general scheme of river improvement in New South Wales, the erection of a barrage (rock-fill weir) on the lower end of Warrell Creek, has been proposed. The aim is to freshen portion of this creek, which is now subject to tidal influence. Local farmers expect that such a scheme would help to stabilise and expand local dairy and vegetable production.

The objectives of the present study are:—(*a*) to describe certain aspects of existing land utilisation in the area, and (*b*) to study the possibilities of increased productivity and changes in the existing pattern of land utilisation that might follow contemplated improvements to Warrell Creek. A statement of suggested methodology is appended.

The area investigated is shown on the accompanying map. It covers some thirty-four holdings bordering Warrell Creek over a distance of 12½ miles upstream from the site of the proposed barrage, the latter being approximately half a mile to the west of Scotts Head. Of these thirty-four holdings, eighteen, comprising approximately 62 per cent. of the total area of the holdings affected by the scheme, were examined in detail. The surveyed farms are scattered through the district and appear to form a fairly representative sample of the entire area. All the statistics quoted in the following section apply to the eighteen farms surveyed.

2. PHYSICAL CHARACTERISTICS OF THE AREA.

The Warrell Creek valley forms a small part of the coastal area drained by the Nambucca River system. Eungai and Allgomera Creeks form the headwater drainage of Warrell Creek. From the junction of these two creeks, the main creek flows for about six miles in a northerly direction. At the Pacific Highway crossing, the stream changes course to an easterly direction skirting the steep slopes which bound the northern bank. To the west of Scotts Head, near the site of the proposed barrage, the stream changes course to a northerly direction running adjacent to Forster Beach until it joins the Nambucca River.

To facilitate description of its physical characteristics, the area surveyed has been divided into two zones (see map): Zone A comprising upper Warrell Creek from the Pacific Highway crossing to the tidal limit, and Zone B comprising Warrell Creek between the Pacific Highway and the barrage site.

Zone A.—This area includes the most productive and intensively settled land in the district. It embraces the following areas:—

(1) Well-drained river flats comprising 8 per cent. of the area surveyed. The soils of these flats are deep and consist mainly of grey sandy loams. They are not under salt influence. In several places there is a steep slope from these flats to the creek, a factor which has inhibited the use of the creek for stock water supplies on some farms. The flats have been cleared for pasture and the cultivation of fodder crops.

(2) Moderate slopes and undulating country (approximately 18 per cent.) bordering the flats and ranging from 10 to 100 feet above sea level. The soils on these slopes are shallow, light-grey loams, well-drained and suitable for vegetable growing on slopes with a northerly aspect. The area has been cleared of natural vegetation and is given over to pasture and crop cultivation.

(3) Steep slopes and ridges comprising approximately 5 per cent. of the area, which are mostly heavily timbered. The soils are shallow and frequent rocky outcrops occur. Vegetation on these slopes consists mainly of typical coastal *Eucalyptus* forests. In some cases, this timber is found as secondary growth in association with sparse pasture growth.

Zone B.—This area is comparatively less fertile and more sparsely settled than Zone A. It comprises the following areas:—

(1) Low-lying flats (comprising approximately 8 per cent. of the area), which are subject to salt influence from Warrell Creek. These swampy flats are found mainly along the southern bank of the creek. Where cleared of natural vegetation, the flats are covered with poor pasture growth, including blady grass, sedges and water buffalo. On the uncleared portions Swampy Oak and Ti-tree may be found. Soils are shallow (2-3 feet) overlying sand deposits. Except for isolated patches of maize on elevated river levees, these flats are not cultivated and provide only poor pasture for stock.

(2) Better-drained river flats not subject to salt influence occurring along the southern side of the creek and adjacent to the swamp flats. These resemble the flats described for Zone A and make up approximately 11 per cent. of the area.

FIG. I.
View of the upper Warrell Creek district (Zone A) showing the extent of the well-drained river flats and moderate slopes typical of the area.

(3) Middle slopes (ten to a hundred feet above sea level) comprising 23 per cent. of the surveyed district. These slopes are largely uncleared, being given over to secondary growth Eucalyptus forest associated with sparse rough pasture. The soils are mostly poor, shallow, and rocky outcrops frequently occur. The slopes facing Warrell Creek are not used to any extent for vegetable-growing, except the areas (with northerly aspect) on the south bank of the creek. The most extensive areas of vegetable-growing in Zone B occur on the slopes with northerly aspect, which lie away from Warrell Creek towards the Gumma swamp area. In this area irrigated vegetable-growing is practised on several farms.

(4) Steep uncleared slopes, comprising approximately 27 per cent. of the area. These support dense coastal Eucalyptus forest and are of limited value.

Climate.

Climatic conditions in the Warrell Creek area are characterised by hot summers and short, mild winters. Average annual rainfall recorded at Macksville over forty years is 52.7 inches, with a tendency for higher monthly averages in summer and autumn. The monthly range is from a minimum average of 2.5 inches (August) to a maximum average of 7.1 inches (March).

Frosts are infrequently recorded at Macksville, although certain local areas are affected. Microclimatic influences are important in determining the use of frost-free slopes for vegetable-growing, particularly in Zone B.

The area experiences considerable variations in seasonal rainfall from year to year. An analysis of the effects of such rainfall variations on the dairy industry has been made for the neighbouring Macksville-Utungan area[1]. Variable rainfall has been reflected in fluctuating levels of production and farm income (see Table II).

River Salting.

Warrell Creek is a perennial stream which is affected by tidal influence to a maximum distance of 12½ miles above the site of the proposed barrage (see map). However, due to variations in the volume of fresh water flowing in the stream, it is only in "drought" years that salinity reaches this point. The portion of the river in Zone A is mostly fresh; frequent brackishness is experienced only in Zone B. Consequently the freshening of Warrell Creek will be most useful in providing stock water in the latter zone, where dry seasons result in inadequate and unsuitable stock water supplies. A number of tributary creeks (such as Snakey, Way Way and Williams Creeks), which drain the hilly country away from Warrell Creek, are perennial and provide permanent fresh water supplies. These are used for stock and irrigation purposes on a number of farms on sections of properties away from Warrell Creek.

[1]N. R. Wills and W. F. Owen, "Farming in Sub-Humid Areas," *Review of Marketing and Agricultural Economics,* Vol. 15, No. 3 (March, 1947), pp. 91-97.

3. PRESENT FARM ORGANISATION.

While much of the district capable of development has been cleared, there are considerable areas under original vegetation or regrowth. The latter comprise approximately 32 per cent. of the area surveyed. However, because of the steepness of topography or unsuitability of aspect, these areas appear to possess little potential value except for rough grazing. Approximately 64 per cent. of the district is under pastures which vary widely in quality. About 13 per cent. of these consist of salted river flats. Portion of the latter is under swamp vegetation, the rest under poor swamp grasses which provide some stock feed, especially in dry seasons. The remainder comprises unimproved and improved pasture. Approximately 4 per cent. of the area surveyed is cultivated, 2.5 per cent. under commercial vegetables (mainly tomatoes, beans and peas), and the remainder (1.5 per cent.) under fodder crops (mainly maize, sorghum and oats) which are used to supplement pastures.

(a) Farm Size.

The average area of the farms in the surveyed district is 285 acres. Settlement in Zone A, however, is more intensive than in Zone B, the average farm size being 200 acres, compared with 350 acres in Zone B. This difference in farm size is possibly a reflection of the difference in natural features between the two zones.

(b) Types of Farming.

The predominant combinations of enterprises in the district are dairying with vegetable-growing, and fat-cattle raising with vegetable-growing.

Table I sets out the various combinations of activities on the eighteen farms surveyed.

TABLE I.

Distribution of Farm Types—Warrell Creek District.

Farm Type.	Number of Farms.
Dairying	1
Dairying and Vegetables	10
Beef Cattle and Vegetables	6
Beef Cattle	1

Of the dairy-vegetable farms, seven derive more than 50 per cent. of their income from vegetables. Vegetable-growing is the main source of income on the farms where vegetable-growing is carried on in association with fat-cattle raising.

(c) Land Tenure.

All of the eighteen farms surveyed are owner-operated. During the past five years, ten of these farms have changed hands, indicating a comparatively rapid turnover of farm ownership.

4. CURRENT PRODUCTION.

(a) Livestock.

At the present time, the average carrying capacity on the eleven dairy farms in the area is one beast to 4 acres. This has been calculated on the total dairy area, excluding that used for growing vegetables. As this figure covers the rough timbered pasture country as well as the

cleared areas, the carrying capacity on the latter is higher. On several of the more highly improved farms in Zone A, where the entire area is cleared and grazed, carrying capacity reaches as high as one beast to 2.5 acres.

(i) Dairy Production.

Table II sets out the total production (commercial butter equivalent) for nine dairy farms in the district over the period 1944-45 to 1948-49.

TABLE II.

Dairy Production on Nine Surveyed Farms—Warrell Creek District.

Year.	Production of Commercial Butter. lbs.
1944-45	30,805
1945-46	38,648
1946-47	26,442
1947-48	35,312
1948-49	36,012
Five-year Average	33,444

The above production figures show the wide fluctuations which have occurred from year to year, due primarily to variations in rainfall received. The sensitivity of butter production to rainfall fluctuations is accentuated by the reliance of many farmers on relatively unimproved pastures and undependable sources of stock water, together with the absence of fodder conservation.

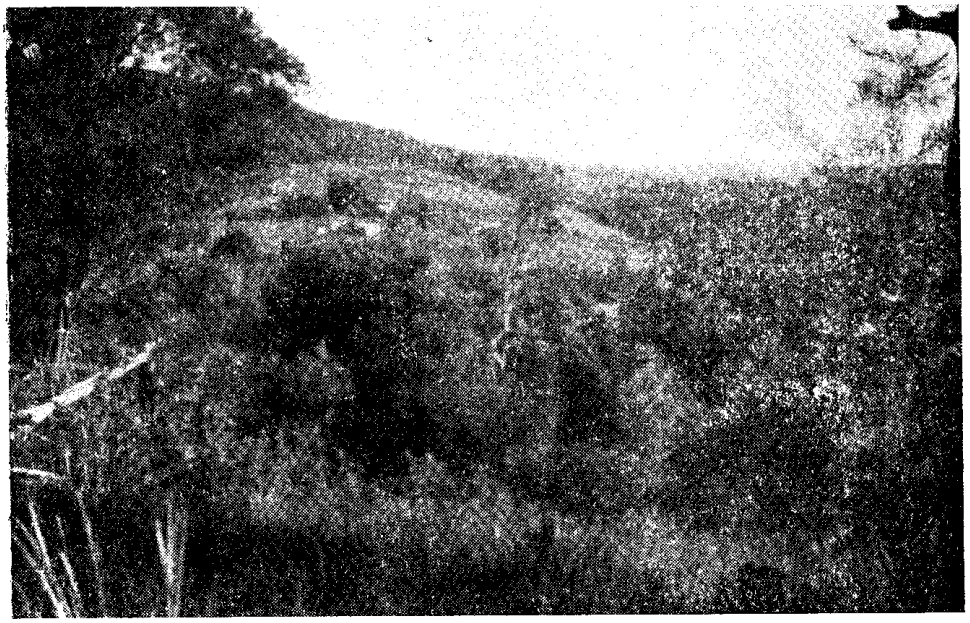


FIG. II.

View of the lower Warrell Creek district (Zone B) showing cleared areas on the slope with northerly aspect, in contrast with the timbered slope with southerly aspect (foreground).

In this district, herd management is such that production is concentrated in the spring and summer months. Only a small percentage of each herd is milked during the winter months. Consequently, the bulk of pasture feed is required during the spring and summer months. However, for most of this period, unreliability of rainfall constitutes a limiting factor to pasture growth.

(ii) Pasture Management.

The area under improved pastures constitutes 14 per cent. of the total area. Most of the improved pastures are paspalum-white clover stands, with kikuyu becoming of increasing importance. Small areas are sown down to an Italian rye-white clover mixture. Pastures thus form part of the vegetable-pasture rotation which, in some cases, directly follows clearing of virgin country. Top-dressing with lime and pasture renovation are practised as a means of maintaining satisfactory growth.

The area under unimproved pastures constitutes 42 per cent. of the non-cultivated area. Included in unimproved pastures are neglected *Paspalum dilatatum* stands which have been invaded by inferior species such as carpet grass (*Paspalum compressum*), blady grass and bracken fern. Some unimproved pasture, consisting of native grasses, provides rough grazing on land covered by secondary growth timber.

(iii) Herd Management.

The majority of the eleven dairy farmers breed their own replacements. As mentioned previously, few farmers aim at maintaining production at a stable level throughout the year. While diminution of production during the winter months is a response to natural conditions, on some farms it constitutes a conscious management policy to enable the farmer to concentrate on winter vegetable crops.

(iv) Pig Production.

Pig production forms a comparatively minor feature of the dairy industry. Six of the eleven dairy farms carry from three to five breeding sows.

(v) Beef Cattle.

Six of the seven beef-cattle producing farms combine this enterprise with vegetable-growing. The beef-cattle farms occur in Zone B and are characterised by an absence of land suitable for grazing of dairy cattle. Here, the steep slopes with unfavourable aspects for vegetable-growing are used as rough grazing. Where suitable soil and aspect occur, restricted areas have been cleared for cash vegetable crops.

(vi) Stock Water Supplies.

Impoverishment of stock water by salting from Warrell Creek and diminution of supply, especially during dry seasons, present a problem to the majority of the dairy farms in the district.

Of the eighteen farms surveyed, five have adequate stock water supplies, even in dry times, derived from fresh creeks draining into Warrell Creek. Some have both natural and artificial dams. Thirteen farms have inadequate water facilities. These farms rely mostly on small wells, usually on the flats, which periodically dry up or become tainted. In some cases, much labour is lost each day pumping water by hand into troughs.

(b) Vegetable and Fodder Growing.

Vegetable growing is confined to moderate slopes with northerly or north-easterly aspects. One of the main considerations for early tomato and bean growing is freedom from frosts during the growing period. One method of evading frosts is to leave uncleared country surrounding the vegetable patches. Due to relatively mild climate, the vegetables can be marketed early so as to bring comparatively high returns. Vegetable farming is on a relatively small scale. Farm mechanisation is limited and farmers rely on contractors for ploughing of the land after clearing. Six of the vegetable farms, in favourable seasons, have adequate water supplies and facilities for irrigation. The chief crop irrigated is tomatoes. The water is obtained from small dams supplied by soaks and fresh water creeks. Movable spray-irrigation equipment is employed.

Availability of labour constitutes a limiting factor to vegetable-growing. Family labour alone is employed on the majority of farms for the cultivation of vegetables. Seasonal labour for harvesting is obtained chiefly from neighbouring centres such as Macksville.

Vegetable yields compare favourably with the average yields for the State. Irrigated tomatoes produce up to 1,500 half-bushel cases per acre, while an average of only 500 half-bushels per acre are produced from non-irrigated crops.

Fodder growing is a relatively unimportant feature of the district. Maize is the major crop cultivated. Other crops include sorghum, oats and roots. Maize is the only crop cultivated on the river flats. Where the latter are subject to flooding and salt influence, maize is grown on small ridges and river terraces bordering Warrell Creek.

Fodder conservation is not practised in the district.

5. RIVER IMPROVEMENT AND SUPPLEMENTARY IRRIGATION.

The authors have examined the projected Warrell Creek Irrigation District with the object of assessing the agricultural developments that might follow the erection of the proposed barrage. The estimates made of future trends are conditional, because in the short time available, accurate data could not be secured on the physical and natural conditions affecting land use in the district, and few of the important socio-economic factors influencing the situation could be measured quantitatively.

The proposed scheme does not involve extensive governmentally-constructed irrigation works and land-use restrictions, as in areas along the Murray River and the Murrumbidgee Irrigation Area. The scope for personal initiative and enterprise by the local farmers is much greater. Hence considerable divergence is possible between what is planned and what may actually eventuate.

If the scheme reaches fruition, the only new factors in the local situation will be:—(*a*) the existence of a barrage and the consequent availability of fresh water; (*b*) the gradual replacement of salt water swamp by fresh water swamp after Warrell Creek is freshened; (*c*) a mandatory charge.

The Warrell Creek scheme comes within the terms of the New South Wales *River and Foreshores Improvement Act* (No. 20 of 1948). This Act provides for the constitution of "irrigation districts" to incorporate the lands benefiting from a scheme. The owners of these "benefited lands" are required to make an annual contribution towards the capital cost and cost of maintenance of the improvement (in this case a barrage). This contribution may be required to cover the whole or part of the capital cost of the work, and takes the form of a mandatory charge per acre on a varying and relative portion of each holding (*i.e.*, the "benefited" area).

The estimated cost of the barrage in Warrell Creek is £8,000. Assuming the total area of the "benefited district" to be approximately 4,000 acres, the contribution per acre would amount to a maximum of approximately 2s. 0d. per annum in perpetuity.

To what extent these changes in local conditions would cause farmers to change the existing pattern of farm organisation was the major problem at issue. A mere agronomic appraisal of the land-use potentialities of the area affected, based on expert opinion, would be a very inadequate answer to the question.

The authors attempted, in the short time at their disposal, to make a realistic forecast of increased production within a two to four-year period. The farm areas were surveyed and an assessment of potentialities made on the basis of farmer's own plans, considering each farm as an operating unit. Such a farm-by-farm survey made it possible to take account of: (1) the differential impact of benefits on the various farms; (2) personal limitations and intentions of existing operators; (3) the availability of farm labour; (4) the resources, both material and financial, available to farmers; and (5) the existing combination of farm enterprises.

The economic development of the Warrell Creek district is subject to the general market situations existing in respect of local industries. In particular, vegetable growing, a major enterprise of the area, is subject to all the risks and market price fluctuations which characterise this industry. While the prices for dairy products are likely to be satisfactory during the currency of the present Commonwealth guarantee, the outlook in the longer run is more uncertain.

The Survey Area.

Of the 34 properties identified in the proposed irrigation district, 29 were investigated. Seven operators stated their opposition to the scheme on the grounds that they would receive no benefits. Their seven farms possess adequate fresh water supplies from small creeks, tributary to Warrell Creek. Four other operators expressed approval of the scheme, but stated that they would receive no benefits in the short-run. The remaining eighteen farmers considered that they would benefit from the scheme, and for their farms an assessment of likely increased productivity was made.

The eighteen farms examined in detail comprise a total of 5,114 acres, or 62 per cent. of the total acreage of the holdings listed for the district. The foregoing description of land use in the Warrell Creek area was based on a study of these farms. These eighteen farms will be referred to hereafter as the "benefited farms."

The principal enterprises of the district, namely dairying, the raising of beef cattle, and vegetable growing, will all benefit from the proposed scheme.

The following summary sets out the short-run economic improvements that may be expected on the benefited farms subsequent to the erection of the barrage. Calculations have been based on: (*a*) the production pattern for the district during the past five years; (*b*) farmers' estimates of expected change in farming practice; and (*c*) assumed market prices based on average levels over the past years.

Livestock Industry.

It is anticipated that there will be an increase in the average numbers of stock carried, involving 52 more dairy stock and three more breeding sows (producing 36 baconers annually). These estimates are based on the assumption that the following improvements are carried out:—

(*a*) The development of 360 acres of fresh-water pasture from existing salt-impregnated flats. It is anticipated, however, that this objective cannot be fully realised until a number of years after Warrell Creek is freshened.

(*b*) The improvement of 221 acres of pasture by—

(1) The conversion of 186 acres of unimproved pasture to improved pasture by top-dressing with lime and fertilizer and sowing improved grasses.

(2) The conversion of 17 acres of unimproved pasture to improved pasture by similar means with supplementary irrigation; and

(3) The irrigation of 18 acres of existing improved pastures.

(*c*) The availability of permanent fresh water for stock and dairy purposes from Warrell Creek. Of the 18 farms examined, 13 have inadequate water supplies during dry seasons.

(*d*) The production of 40 additional acres of fodder crops (15 acres of oats, 10 acres of sorghum and 15 acres of miscellaneous crops.)

These improvements should result also in an overall increase in yields per head of dairy stock carried. However, because of the limitations of the survey, it is not possible to state precisely what these increases might be.

In an earlier investigation of the Macksville-Utungun district, in close proximity to Warrell Creek, Wills and Owen have shown the manner in which seasonal climatic variations have been largely responsible for considerable fluctuations in the monthly and annual production of dairy herds[2]. As Macksville is the only meteorological station for the Macksville-Utungun and Warrell Creek districts, the conclusions of the above analysis can be applied in principle to the Warrell Creek district.

The reader is referred to Table II, which sets out the production in terms of commercial butter on nine of the farms under survey, over the period 1944-45 to 1948-49. Production is concentrated in the spring

[2] *Ibid.*

and summer months to take advantage of maximum seasonal pasture growth. However, rainfall has been shown to be relatively unreliable during this period.

The difference between production in 1945-46 (a "favourable" year) and that in 1946-47 (a "drought" year) amounted to 12,206 lbs. of commercial butter. For the most part, this difference can be attributed to differences in climatic conditions between the two years.

Because of the uncertain incidence of seasonal droughts in the North Coast, it is impossible to estimate for any particular period the actual contribution of the proposed scheme towards reducing the serious random fluctuations in the output of dairy products that have characterised the area in the past. Nevertheless, it is thought that this stabilizing effect on production may be of major importance to the district and be at least as important to the individual producer as the direct increase in production detailed below.

Assuming a continuation of the present average yield of commercial butter per head of dairy stock, a minimum figure for the expected increase in milk production can be given. Applying the average yield to the expected increase in dairy stock (52), it is expected that production from the surveyed area will be increased by 3,120 lb. of commercial butter. At an average value of 2s. 0d. per lb., this is equivalent to £312 increase in annual gross revenue to the farmers concerned.

The expected increase in yearly pig production (thirty-six baconers), based on an average value of £6 10s. a head, will mean an additional £234 gross revenue to the farmers in the district.

On the basis of the programme of pasture improvement and improved stock water supplies outlined above, three non-dairy farms are expected to increase the total beef cattle carried each year by sixty-five head. At an estimated value per head of £10, this will represent an additional gross return of £650 to the district.

Vegetable Industry.

The benefited farms are expected to expand the area devoted to vegetable production by 31½ acres, which are to be irrigated. In addition, a portion of the existing non-irrigated acreage growing vegetables will be irrigated and produce increased yields.

Table III shows the anticipated increase in annual production:—

TABLE III.

Anticipated Minimum Increase in Annual Production on Sixteen Farms, Warrell Creek District.

Crop.	Additional Production.	Average Market Value per bushel.	Gross Value of Increased Production.
	Bushels.	£ s. d.	£
Tomatoes	6,000	2 0 0	12,000
Beans	1,675	0 12 6	1,047
Peas	1,590	1 1 0	1,670
Cucumbers	650	1 0 0	650
Total			15,367

It is believed that an estimate of £15,000 for the additional gross return for vegetables is conservative.

Because of limited labour and capital resources, the majority of farmers interviewed see the Warrell Creek improvement scheme as a means of stabilizing and increasing production on acres at present used for vegetable cultivation. Only four farmers anticipate being able to handle larger crop areas than at present.

Cost of Irrigation.

The increase in production previously described can only be obtained at the expense of some increase in the total costs of farming per acre. However, it is anticipated that the increased revenue per acre will offset these costs and leave a considerable margin of profit.

This can be illustrated by estimating the additional costs per acre which must be expended to realise the increase in yield per acre of tomatoes under irrigation. These additional costs have been calculated to amount to £370 per acre, as compared with an additional gross revenue of £1,000 per acre. Therefore, without taking current net profits into account, irrigation of tomatoes is expected to return an additional net profit of £630 per acre.

In applying the abovementioned additional costs to irrigated tomato growing, due to lack of data, it has been assumed that irrigation improvements will not result, in the short run, in a more efficient use of existing factors of production. To this extent, it is possible that the assessment of benefits has been understated.

Irrigation of pastures for dairy herds is not practised to any extent in areas similar to the Warrell Creek district. Hence it is not possible to indicate the additional costs that would be involved in the maintenance of irrigated pastures. However, as with vegetable growing, it is expected that the increase in revenue derived from irrigation will more than offset such costs.

Summary of Short-term Benefits.

Table IV provides a summary of minimum short-term benefits assessed in quantitative terms.

TABLE IV.

Summary of Minimum Short-term Benefits from Irrigation on Eighteen Farms—Warrell Creek District.

Source of Increased Production.	Gross Value. £
Butter	312
Pigs	234
Beef Cattle	650
Vegetables	15,367
Total Increase in Gross Revenue ..	16,563

Long-term Benefits.

The assessment of the short-term benefits has been defined by such considerations as the intentions and resources of existing farm operators. Taking a longer view, the economic effect of the freshening of Warrell Creek on the development of the district may be much more profound. The present form of land use consists of dairying based on relatively

unimproved pastures, in association with restricted patches of intensive cultivation. The district is potentially capable of a considerably higher level of production than that attained by existing farmers. Availability of permanent water supplies from Warrell Creek would provide an incentive for the gradual subdivision and consequent intensification of agricultural production far beyond that attained under present farm organisation. The authors have not attempted a forecast of the possibility or extent of likely development along these lines.

6. SUGGESTIONS AS TO METHODOLOGY.

The survey of the Warrell Creek district outlined above can be best described as being of a reconnaissance type. Experience gained in the course of the survey has led the authors to give consideration to the desirable form of a more thorough survey to determine the economy of supplementary irrigation in specific areas. In the concluding paragraphs of the article, an outline of the scope and content of such a survey is given.

Such a survey would involve in the first instance a detailed study of the present-day land utilisation and the physical characteristics of the project area. An analysis of the physical and natural features and the relation between these and the land use, both in its present form and through historical time, provide a secure foundation for assessing the economy of any developmental programme.

Assessment of the potential productive capacity of land under irrigation involves, in addition, research into the numerous social and economic factors, both local and national, which influence the character of activities in the district. The following is a summary of the factors that should be considered for a developmental area as restricted as that covered by the proposed Warrell Creek Improvement Scheme.

A. Physical and Natural Factors.

The physical data collected for a restricted area should include the following aspects:—

(i) Soil.

Soil and related geological conditions should be carefully considered with regard to suitability for potential utilisation, both by irrigation and non-irrigation farming. An accurate knowledge is essential of such factors as (1) character and composition of the soil profile; (2) soil texture; (3) soil structure; (4) salinity and alkalinity, and (5) drainage, external and internal. A survey of the distribution of soil types based on an analysis of these factors should be undertaken. The mapping of the different classes of soils in relation to variations in topography will be of value in classifying the land on the basis of irrigability and potential productivity under irrigation. The incidence, nature and susceptibility to soil erosion throughout the area should be carefully ascertained.

(ii) Topography.

The character of the topography constitutes an important factor in determining the suitability of land for agricultural purposes. The steepness of slope affects the nature of both soil erosion and sub-surface

drainage. Progressive increases in gradient of slope make tillage operations more difficult. As indicated below, direction of slope affects the value of the land for arable purposes. An accurate and detailed study should therefore be made of topography throughout the area.

(iii) Climate.

General climatic conditions should be considered, such as the broad climatic limits to the use of the land in the project area. More important than these, however, will be the micro-climatic factors which, in conjunction with localised aspects of topography and soil, influence the use and productive capacity of the land.

The object of micro-climatic studies is to map the distribution of local climatic factors found to be critical for the successful growing of crops which the general climatic conditions and other physical factors make profitable in the project area. Micro-climatic analysis should cover such aspects of climate as (1) the occurrence or absence of killing frosts during the growing season; (2) the occurrence of thermal belts and the intensity of sunshine in protected pockets and on slopes with favourable aspects; (3) the occurrence of strong winds; (4) local occurrence of hail and destructive storms; (5) incidence of cloudiness; (6) occurrence and duration of daily sunlight in restricted areas.

(iv) Additional Factors.

The nature and occurrence of natural and introduced vegetation, the availability of water supplies and the character of the river regime, should also be considered in the survey of physical factors. The data which is collected on the physical and natural features of the area should be critically analysed to evaluate the combined effects of the various factors on the character of agricultural activity, particularly as regards the potential levels of production under irrigation.

B. Economic and Social Factors.

The development and character of land utilisation in an area is the result of the interaction of the aforementioned physical factors with a number of economic and social factors. Many of the vital relationships in the pattern of the land use will be found to be economic in character.

Any thorough survey would involve the following:—

(i) A description of the economic conditions, such as markets and industries using the products of the area and absorbing excess rural labour.

(ii) An assessment of the present productivity of the various enterprises in the district and a study of trends in same.

(iii) The assembly of price series for the products of the area.

(iv) The assembly of price series for the various factors of production, *e.g.,* farm labour and current farming requirements.

(v) A study of the conditions of supply of farm labour, particularly seasonal labour.

(vi) An analysis of farm income structure in relation to the various existing and potential combinations of farm enterprises, in order to assess the profitability of such combinations.

(vii) The assembly of information concerning other social factors which influence the character of land utilisation, such as—

(1) Land tenure—present status and trends.

(2) Farm management in relation to relevant social and economic factors.

(3) Population—occupational distribution, movements, structure and composition.

(4) Land values—present levels and trends.

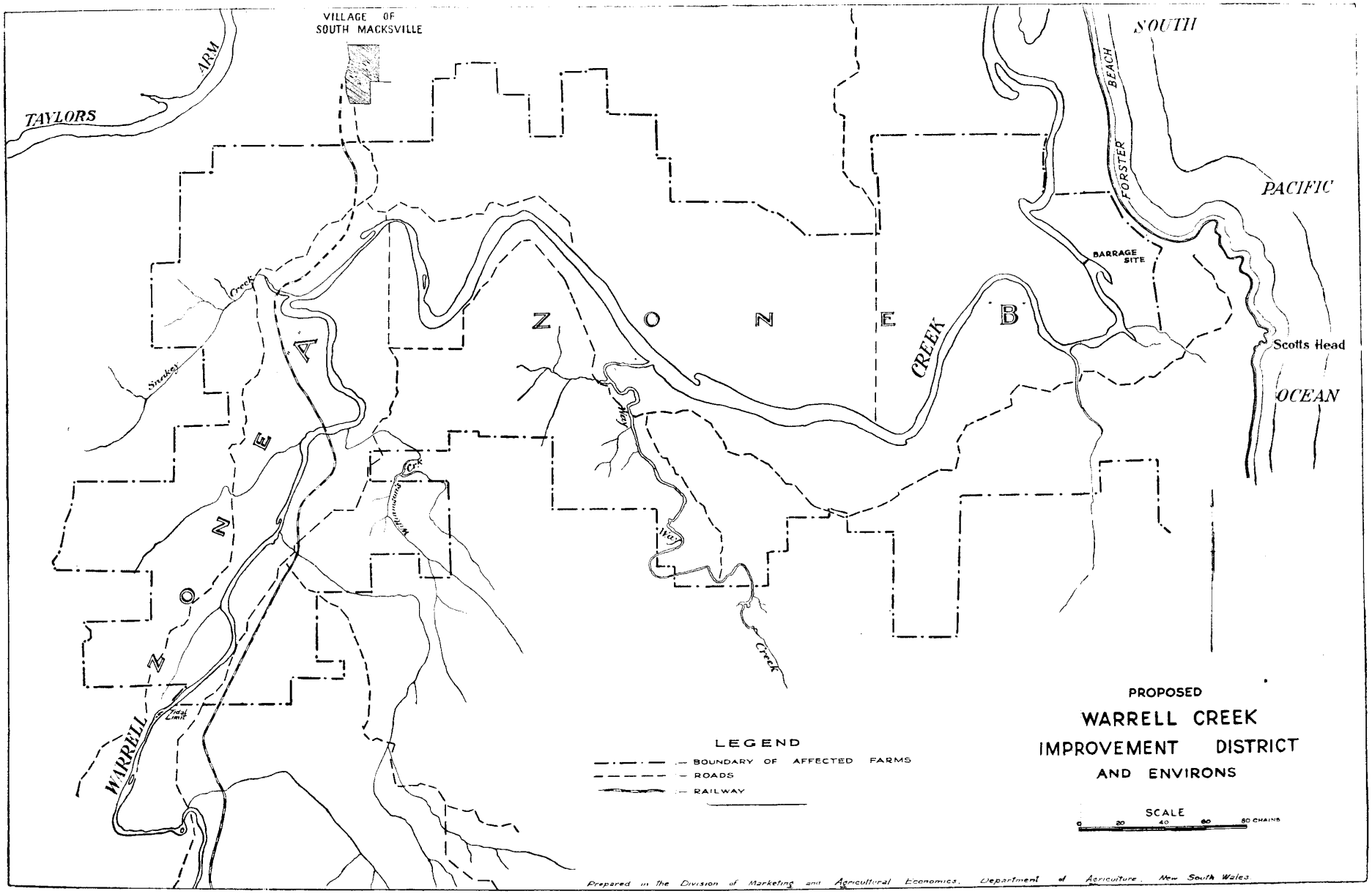
(viii) The use of the abovementioned data to analyse the economic feasibility of a contemplated scheme of irrigation and river improvement. Such an analysis should be concerned with :—

(1) The various costs to be incurred and the net earning power of land under different uses and combinations of uses if irrigation is employed.

(2) The ability of the various farmers to withstand the costs involved and to undertake the planned development, considered in relation to current indebtedness and the developmental period required. The availability and nature of rural credit is very relevant in this regard.

(3) The benefits of the proposed scheme to other district interests, *e.g.,* commercial and industrial interests.

(4) Its relation to the broader problems of irrigation and river improvement, in particular, the questions of general State development, external market conditions and the consensus of political opinion.



† 46543—To face page 138.