Fig. 4.1: Present-day physiographic conditions of the Clarence fluvio-estuarine basin.
Fig. 4.2: Holocene sea-level envelope for southeast Australia for the last 15,000 years (After Thom and Roy, 1983).
Fig. 4.3: Hypothetical model of the Clarence fluvio-estuarine basin at 7,500 years B.P.
Fig. 4.4: Hypothetical model of the Clarence fluvio-estuarine basin at 5,000 years B.P.
Fig. 4.5: Hypothetical model of the fluvio-estuarine basin at 2,500 years B.P.
Fig. 4.6: The deltas in Gippsland Lakes in southeast Australia (After Bird, 1965). (A) Gippsland Lakes with elongated deltas, such as, Mitchell Delt. (B) Close up view of the Mitchell Delta with different geomorphic units. (C) Sections through the Mitchell delta; the locations of the sections are shown in (B). (D) Protruding shape of the Latrobe and Tambo Deltas in Gippsland Lakes.
Fig. 4.7: Palaeo-environmental interpretation of selected drill holes in the Clarence Fluvio-estuarine basin (Chappell, pers. comm.). For locations of the drill holes, see figure 4.1.
Fig. 4.8: Logs of selected drill holes that penetrate estuarine deposits within inner basin of the Clarence River. For location of holes see figure 4.1. Holes numbers in boxes indicate radiocarbon date from that hole.
5. Morphostratigraphy of Point-Bar Plains

5.1 : Introduction:

For the purpose of this study, a point-bar plain is defined as a dominantly well vegetated body of sediment enclosed by a convex bank, with elevations close to the adjacent floodplain but distinctly different from the floodplain, in its surficial morphology. This definition of point-bar plains, essentially relates to their geomorphological composition and position with respect to the river bank. Point-bar plains are composite geomorphic units, consisting of several simple geomorphic units, namely, levee, platform, chute channel and occasionally marginal point bars. Within the study area three point-bar plains have been identified, namely, Carr, Southgate and Cowper bars (Fig.2.3).

5.2 : Morphology of point-bar plains:

Descriptions of the morphology of the point-bar plains basically include characterisation of their surface configurations. Data are not available to delineate the bottom configuration of point-bar plains, but it is expected that the basal surface will trace the migration of the adjacent channel bottom, because point bars are marginal to the active channels. The lateral boundaries of the point-bar plains are vertical or dip towards the main channel (Fig.5.4).

Most part of the upper surfaces of point-bar plains (which form the platforms) are horizontal to slightly sloping away from the main channel and are traversed by narrow levees and chute channels, which are parallel or sub-parallel to the main channel. A schematic cross-section of point-bar plains is shown in figure 5.4. The average elevation of these plains is about 3 to 3.5 metres above AHD. The point-bar plains are crescentic in planform and are up to several kilometres long and several 100's of metres wide. The length of Carr bar is about 5.5 kilometres and it is slightly over a kilometre wide; the Southgate bar is about the same size as Carr bar while Cowper bar, which is the smallest of its kind, is about 3.5 kilometres long and 500 metres wide. The Carr bar has a levee bordering the main channel and an abandoned levee in the middle of the bar
(Fig.5.1). Two chute channels occur on the Carr bar, the larger one borders the abandoned levee in the centre of the bar and the other separates the Carr bar from the main floodplain (Fig.5.1). Southgate bar has four levees and chute channels (Fig.5.2) and the Cowper bar has two levees and a chute channel (Fig.5.3). Chute channels of the point-bar plains often occur immediately riverward of abandoned levees, which suggest that chute channels were guided by the former levees at the time of their formation. The surfaces of the point-bar plains that lie between levees and chute channels are designated as platforms. The Southgate point-bar plain has an active marginal point bar along the downstream reach of its outer margin (Fig.5.2), but other point-bar plains have no presently active marginal point bars.

5.3 : Sediment characteristics of point-bar plains:

The point-bar plains consists of two genetically different groups of sediments, namely, (i) laterally and (ii) vertically accreted. Genesis of these sediments is inferred from their texture and position with respect to the mean water level of the main channel. A moderately to well sorted medium sand body, whose upper surface occurs about 1 to 1.5 metres above the mean water level is the lateral extension of the active point bar at the margin of the Southgate point-bar plain, and is considered to be a lateral accreted deposit. Overlying the well-sorted medium sand, is a body of moderately to poorly sorted fine to very fine sand, which is continuous across the point-bar plain and is considered to be vertically accreted from the overbank floodwater. Vertically accreted deposits overlie those of lateral accretion in each point-bar plain (Fig.5.4). The upper surface of the lateral accretion deposits generally occurs at about 1.5 metres above AHD and its thickness is inferred to be up to about 11 metres. No drill hole penetrated to the base of the laterally accreted sand bodies of the point-bar plains. Drill hole PB 2 showed that the lateral sediments occur to at least 8 metres below AHD (Fig.5.6). The mean depth of the thalweg of the main channel is about 10 metres and the lateral sand body represents point bar progradation of the migrating channel. The upper surface of the vertically accreted deposits, can have variable elevations due to differences in the elevations of platforms and levees of the point-bar plains. Platform surfaces are mostly about 3 to 3.5 metres above
AHD; and the average thickness of the vertically accreted deposits is about 2 to 3 metres, though greater at the levees (Fig.5.4). The laterally accreted deposits consists of moderately sorted medium and coarse sands, described in chapter 3 (Fig.3.11 and table 3.1). Vertically accreted deposits consist of muds, very fine and fine sands. Muds and very fine sands are commonly poorly sorted while fine sands are moderately sorted. Most of the sediments of the point-bar plain are strongly fine skewed (Chapter 3, figure 3.11 and table 3.1).

The top of the lateral accretion deposits in Carr bar occur at about 1.5 metres above AHD and there is a gentle slope (of the order of 10 to 20 centimetres vertical difference across the point-bar plain, which is about 750 metres wide) of this surface towards the main channel (Fig.5.5). Unlike other point-bar plains, the lateral accretion deposits of Carr bar, also include moderately well sorted fine sand. The upper surface of laterally accreted deposits in Southgate bar also has a gentle slope but unlike Carr bar, away from the main channel (Fig.5.6). This magnitude of this slope is about 30 centimetres in about 950 metres of horizontal distance across the bar. In Cowper bar, the upper surface of the laterally accreted deposits slope by about 70 centimetres towards the main channel from its distal part which are separated by about 750 metres of horizontal distance (Fig.5.7).

The vertical accretion deposits of Carr bar have a greater thickness than other point-bar plains (Fig.5.5). For most part of this point-bar plain, this is about 4 metres, while along certain narrow belts on the bar, which are covered by levees the thickness is about 6 metres. The elevation of the top surface of the vertically accreted deposits vary between about 5.5 to 7.5 metres above AHD. Thickness of vertical-accretion deposits on Southgate bar is generally about 2 metres and along certain levees this can be up to 5 metres (Fig.5.6). Elevation of the top of these deposits in Southgate bar can vary between 3.5 to 5.5 metres above AHD. Vertical-accretion deposits on Cowper bar are generally about 2 metres and can be up to 3.5 metres (Fig.5.7) and the top of the upper surface of these deposits occur at elevations between 3.3 to 4.7 metres above AHD. The vertical-accretion deposits on Carr bar is different from those of other point-bar plains in having
more muds and no fine sand (Fig.5.5). Vertical-accretion deposits on Southgate and Cowper bars are almost all very fine to fine sand (Fig.5.6. and 4.7). Fine sands mostly occur along narrow belts on these point-bar plains which are covered by levees whereas very fine sands occur mostly in their flat areas which are platforms.

5.4 : Morphostratigraphy of elements of the point bar plains :  

5.4.1 : Levees and Platforms : 

The levees on the point-bar plains are long, relatively narrow ridges. Their boundaries facing the main channel are steep and nearly vertical while the opposite boundaries slope gently (2° - 4°) to the adjacent platform. Levee sediments pass downwards into platform sediments and there is no distinctive horizon separating the two morphostratigraphically. Levees are distinguished from platforms purely by their upper surface. Levees are often 10's of metres wide, 100's of metres to several kilometres long and generally stand 1.5 to 3 metres above the adjacent platform (4.5 to 6 metres above AHD). In the Carr bar, where levees are well developed along the main channel margins, the marginal levee is about 110 metres wide and about 3 kilometres long whereas an abandoned levee in the central part of the bar is 80 metre wide and 1.5 kilometre long (Fig.5.1). The elevation of levees in Carr bar is higher than those of other bars and are generally up to 7.5 metres above AHD. In Southgate bar, most of the levees are about 50 to 60 metres wide and about a kilometre long (Fig.5.2), although one abandoned levee runs for almost the entire length of the bar. The elevations of the levee in Southgate bar vary between 4 to 6 metres above AHD. Levees in Cowper bar are least extensive, covering only a fraction of the bar (Fig.5.3). There are two of these, each about a kilometre long and about 80 to 90 metres wide.

The levees and platforms of point-bar plains are vertically accreted sediment bodies dominantly composed of moderately to poorly sorted fine very fine sands, sometimes fining upwards to muds, specially in the platforms. Grain size analysis of representative samples of levees and platforms within point-bar plains were summarised in Table.3.1 and figure 3.11 of Chapter 3. The bottom of the levee and platform deposits is the top of the coarser lateral-accretion deposits, about 1 to 1.5 metres above AHD. The
very fine sands are moderately sorted, this is consistent with sediments in levees of other point-bar plains, but the occurrence of mud in between the two very fine sand layers make it difficult to infer the position of the bottom of the levee.

5.4.2: Chute channels:

Chute channels of the point bar-plains are presently filled with sediments and they are non-flowing at mean water level of the main channel. Their top surfaces generally have concave-up shape whereas sides are vertical to gently dipping and the shape of the bottom surfaces are not known. Chute channels are generally straight and single channelled and can be several kilometres long and 10's of metres in width. The average elevations of the tops of the chute channels are about 1 metre above AHD. The depth of the chute channels are about 2.5 metres. These channels are often located immediately adjacent to levees, on their main channel side. The most common sediments of the chute channels are muds which are poorly sorted although moderately sorted fine sands may occasionally occur.

5.4.3: Marginal point bar and laterally accreted deposits:

A marginal point bar is a body of sediment, within the active channel, which is bare or sparsely vegetated and extends downstream from the apex of the outer margin of the point-bar plain. It is narrow and roughly flat topped. Highest elevations occur along its outer margin which is about 2 metres above AHD. The marginal point bars do not diverge from the main bank of the point-bar plains toward their downstream end and there are no backwater channels. There is only one marginal point bar in the study area and this occurs in the Southgate point-bar plain (Fig.5.2). This bar is about 850 metres long and has a maximum width of about 170 metres. The bar is narrow at the upstream end and widens downstream. Marginal point bars are almost entirely composed of lateral-accretion deposits. From the available data, it is seen that these lateral-accretion deposits are composed of medium sand and they are part of the lateral-accretion deposits of the point-bar plains as a whole.
5.5: Sedimentation model for point-bar plains:

Point-bar plains form through deposition of lateral-accretion deposits, prograding from the convex bank of the main channel, which subsequently are covered by finer textured sediments that accrete vertically from overbank floodwaters. Lateral accretion occurs in alternating rapid and slow phases; levees develop when lateral accretion is slow whereas platform surfaces between successive levees represent phases of rapid lateral accretion. A sedimentation model of point-bar plains is given figure 5.8 which shows three phases for both lateral (L-1, L-2, and L-3) and vertical (V-1, V-2 and V-3) accretion. It also includes two phases of chute-channel activity (C-1 and C-2). To explain the sequences of sedimentation in figure 5.8, sedimentation of phase one (L-1, V-1 and C-1) is discussed here. Rapid part of L-1 are the first sediments to be deposited which are followed by those of rapid of V-1 (Fig.5.8). Then the rate of sedimentation slows and L1S is deposited and subsequently covered by V1S. Subsequently, during floods, chute channel (C1) is formed which is guided by the convex bank in this case and by levees in others. The rate of sedimentation is inferred from the surface morphology of the point-bar plains. When the lateral shifting of the main channel is rapid, no given area on the point-bar plains remain in close proximity of the main channel for a long time and therefore features like levees can not form and hence, the surface of the point-bar plain remain flat. When the rate of lateral shifting of the channel is slow, any given part of the point-bar plains can remain in close proximity to the channel for a longer period of time which allows levees to form because of repeated sedimentation along the proximal belt of the channel.

Second (such as L2, V2) and third (such as L3, V3) phases of point-bar progradation take place in a similar fashion to that of phase one (L1, V1 and C1). The processes that form point-bar plains are identified as lateral and vertical accretion. The lateral accretion deposits are dominantly medium to coarse sand while those of the vertical accretion are dominantly very fine to fine sand. Lithologically, lateral-accretion deposits are more or less uniform laterally while there are lateral variations in lithology in the vertical-accretion deposits. In areas, covered by platforms, the vertical-accretion
5.6: Discussion:

Point-bar plains are a relatively minor features in the Clarence floodplain compared with the scroll plains of actively meandering rivers (e.g. Wolman and Leopold 1957, Nanson 1980, 1981) and tidal rivers (e.g. Daly River, Northern Territory, Australia: Chappell 1993a), where the scroll plain makes a continuous tract through which the river meanders. Active point bars occur at almost every bend in such cases. Not only is the process of point-bar migration slow within the floodplain of the study area (perhaps consistent with very gentle planform curvature of the channel) but it occurs very sparsely. At the present time, there is almost no lateral progradation of point-bar plains. Hickin (1974) identified the channel curvature as a critical factor for direction and rate of meander migration. Hickin and Nanson (1975) described that the channel-bend migration is maximum when $r/w_m$ ratio ($r$ is the radius of curvature of the meander bend and $w_m$ is the width of the channel at that point) of the channels is 3.0 and that the migration can rapidly decline if this number is greater or less. Within the study area, the $r/w_m$ is greater than 4. Very slow rate of meander-bend / point-bar plain migration relates to the lateral stability of the main channel.

The preservation potential for the deposits of the point-bar plains are high. Except for the area of these bars where chute channels are formed, there are no evidence of erosion either in the surface or in sediment body of these units.

Point-bar plains of the study area are composed of upward fining sedimentary sequences (vertical-accretion deposits are finer than those of lateral accretion). Fining-upward sequences for point bars have been widely described in fluvial literature (e.g. Fisk, 1947; Sundborg, 1956; Fraizer and Osanik, 1961; Allen, 1965b, 1970 a, b; Vischer 1965, Bridge, 1975; and Nanson, 1980). Lateral accretion as a process of sedimentation at the basal part and vertical accretion as such process for a point-bar plain has been described by Nanson (1980) and Bridge (1975).
Fig. 5.1: Geomorphic units of the Carr bar. Section through holes RB2, PB1 and CB1 is shown in figure 5.5. For location of the Carr Bar within the study area, see figure 2.3.
Fig. 5.2: Geomorphic units of the Southgate Bar. Generalised cross-section of this bar is presented in figure 5.6. For location of this bar within the study area, see figure 2.3.
Fig. 5.3: Geomorphic units of the Cowper Bar. Generalised cross section of this bar is presented in figure 4.7. For location of the Cowper bar within the study area, see figure 2.3.
Fig. 5.4: Schematic cross-section of point-bar plains.
Mean base of the main channel is about 10m below AHD.

Fig. 5.5: Generalised cross section of the Carr point-bar plain. For locations of holes see figure 5.1. Bracketed numbers in italics are hole-top elevations in metres with respect to AHD.
Fig. 5.6: Generalised cross section of the Southgate point-bar plain. For location of holes see figure 5.2. Bracketed numbers in italics are hole-top elevations in metres with respect to AHD.
Fig. 5.7: Generalised cross section of the Cowper point-bar plain. For location of holes see figure 5.3. Bracketed numbers in italics are hole-top elevations in metres with respect to AHD.
Mean base of the main channel is about 10m below AHD.

Sequence of sedimentation phases:
L1R → V1R → L1S → V1S → C1
→ L2R → V2R → L2S → V2S → C2
→ L3R → V3R
R=Rapid, S=Slow

Legend:
- Vertical accretion deposits
- Lateral accretion deposits

Scale:
Vertical: 0.5m
Horizontal: 50m exaggeration: x 100

Fig. 5.8: Sedimentation model of point-bar plains.
6. Morphostratigraphy of Levees

6.1: Introduction:

In planview, levees are narrow elongated sedimentary ridges bordering a channel, with a steep side adjacent to the channel and an outward gentle slope towards the adjacent plain. Levees represent vertical accretion of sediments from overbank floods, and they pass laterally into plains including platforms in the point-bar plains. The exact configuration of subsurface lateral and bottom boundaries of levees were not identified, but the base of these units are identifiable in auger holes from the change in sediment characteristics and their the elevations. In sediments underlying levees, significant coarsening of grain size commonly occurred within a few centimetres to a metre above the mean water level of the main channel. This interface of finer and relatively coarser sediments is considered to represent the bottom of the levees. Levees occur in three geomorphic zones within the study area: (i) bordering the main and branch channels (including point-bar plains), (ii) bordering channels within straight channel zones and (iii) within sinuous channel zones. Levees bordering the main channel are active, those in the distal part of the point-bar plains away from the main channel are abandoned while those within the floodplain channel zones are relict.

6.2: Dimensions, elevations and spatial distribution:

The levees of the study area are 100's of metres to several kilometres in length, 10's to 100's of metres in width, and their tops can be in excess of 6 metres in height above AHD, but most are generally 3 to 4 metres. Levees along the main channel (Figs.2.4, 2.5, 2.6 and 2.7) are generally wider (about 250 metres) than those (Figs.2.13, 2.14, 2.15 and 2.19) within the floodplain-channel zones (about 50 to 150 metres). There is no significant difference in the widths of levees between those within straight channel zones and sinuous channel zones. However, between channel zones, levees may be better developed in some than others. Levees are better developed in the straight channel zone of Tucabia floodplain (Fig.2.13) than those of the straight channel zone of Calliope floodplain (Fig.2.14). In case of sinuous channel zones, levees in the Grafton
floodplain are better developed (Fig.2.19) than those within the same type of channel zone in the Tucabia or Calliope floodplains (Fig.2.20). Levees occur along both sides of the main channel, along almost its entire length (Figs.2.4, 2.5, 2.6 and 2.7) while within channel zones, in some cases, levees are absent or developed only on one side of the prominent channels, as within straight channel zone of the Calliope floodplain (Fig.2.14). However, contrary to this, along some of the channels within the channel zones, levees can be well developed along both sides of the channel, as in the straight channel zone of Tucabia floodplain (Fig.2.13). Levees along the branch channel, in the Calliope floodplain, are well developed along its southern (right) bank (Fig.2.6) whereas on the opposite bank, in the Woodford floodplain, gaps occur between its levees (Fig.2.7). This is possibly related to levee breaching by chute channels. No surface expression of such chute channels are present however, in this part of the floodplain; but a chute-channel zone is located further downstream of the floodplain. Tops of the levees along the main channel are generally about 5 metres and those within floodplain-channel zones are generally about 3 to 3.5 metres above AHD.

6.3: Sediment characteristics:

They are mostly composed of moderately sorted fine to very fine sands. Grain-size analysis of representative samples of levees were conducted and the results have been presented in Table 3.1 and figure 3.11 of Chapter 3. There is no significant difference in the sediment composition of the levees of the main channel (Figs. 6.1 and 6.2) and those within floodplain-channel zones (Figs.6.3 to 6.6). Sediment bodies of levees along the main channel are generally thicker (in the order of 3 to 4 metres, figures 6.1 and 6.2) than those within floodplain channel zones (which are mostly between 2 to 3 metres, figures 6.3, 6.4, 6.5 and 6.6). Bottoms of levees, in all cases occur above AHD (Figs.6.1 to 6.6) and their elevations are variable mostly between a few 10's of centimetres (Fig.6.3) to up to 3.5 metres (Section B of figure 6.1) above AHD.

Thicknesses of sediment bodies in levees along the main channel can be variable (Figs.6.1 and 6.2). In the Grafton floodplain, these levees are thicker (about 4 metres) than those in any other floodplain (which are generally about 2.5 to 3 metres).
Thicknesses of sediment bodies of levees can be either uniform or variable. In the Grafton floodplain, the levee along the main channel has uniform thickness (section A of Fig.6.1) while thicknesses of levees in the Tucabia-Calliope (section B of Fig.6.1) and Woodford floodplains (Section A of figure 6.2) have variable thicknesses and consequently the bottoms of these levees occur at different elevations. The tops of levees along the main channel are generally higher in the upstream parts of the floodplain (that is in the Grafton floodplain), which decreases in elevation towards the downstream part of the floodplain (that is towards Woodford floodplain).

Within straight channel zones, the sediment bodies of levees of the Tucabia floodplain are thicker (mostly about 2.5 metres, Fig.6.3 and 6.4) than those of the Calliope floodplain (mostly about 2 metres, figure 6.5). Woodford floodplain has the thinnest levees of these channel zones (slightly over a metre, figure 6.6, section A).

6.4: Genetic units underlying levees:

Levees within the study area are underlain by sediments of other origin. These sediments were examined to determine their environment of deposition. Plain, swamp and within-channel (lateral-accretion sediments in the diagrams) environments were identified, mainly on the basis of their lithology. Plains were identified by their poorly sorted very fine sand or sandy mud while swamps were identified by their poorly sorted muds. The lateral-accretion deposits were identified by their moderately sorted medium sand texture and elevations at which their top surfaces occur. Sediments of fluvial origin are underlain by those of estuarine origin. The estuarine deposits are identified mainly by the presence of shells.

The levees of the main channel in the Grafton floodplain are underlain by lateral-accretion deposits (Fig.6.1). These deposits also occur beneath levee deposits in the downstream part of the Woodford floodplain (Fig.6.2). These indicate localised lateral shifting of the main channel in the direction of the opposite bank at these parts of the floodplains. Plain sediments occur underneath the levee deposits for much of the length of the levee in the Tucabia and Calliope floodplains (Fig.6.1) suggesting that localised lateral migration of the main channel occurred in the direction of the
floodplain. However, at the central downstream part of the Calliope floodplain, a point-bar plain is attached to the bank of the main channel. This suggests that at this part of the Calliope floodplain, the lateral migration of the channel has been in the direction of the opposite bank. Plain sediments also occur at the upstream part of the Woodford floodplain.

In the straight channel zone of Tucabia floodplain, levee deposits are mostly underlain by lateral-accretion deposits and occasionally by those of swamp or plain (Fig.6.3 and 6.4). Vertical distributions of these genetically related sediments indicate localised lateral shifting of the channels within this straight channel zone.

The levees of the straight channel zone of the Calliope floodplain are mostly underlain by sediments of either only plain or both plain and lateral accretion (Fig.6.5). These vertical stacks of sediments also indicate localised lateral shifting of the channels within the channel zone. In this floodplain-channel zone, crevasse sediments also occur underneath levees (Fig.6.5). This is indicative of levee breaching and formation of crevasse channels.

In the straight channel zone of Woodford floodplain and in the sinuous channel zones of Grafton floodplain, levee deposits are underlain by those of plain and lateral accretion (Fig.6.6). These vertical stacks of sediments are indicative of localised lateral shifting of the channels.

6.5. Discussion:

There are no abandoned levees along the main channel on the floodplain which reflects that the main channel within the study area is laterally stable. However, abandoned levees occur in point-bar plains within the main channel which are indicative of lateral shifting of the main channel. But these point-bar plains are only minor features of the floodplain and hence, the lateral movements of the main channel are localised events. The levees within the floodplain-channel zones are relict features. They were only active when the channels bordering them were active. The levees of the main channel are higher and wider than any of the relict levees of the floodplain.
Preservation potential of the levee deposits of the study area is high. Abandoned levees on the point-bar plains have been well preserved, and present levees are also well developed. Within the sediment bodies of these levees there is no evidence of erosion, and older deposits of the levees have been well preserved.

Reineck and Singh (1980) mentioned that the maximum height of the levees can sometimes act as indicators of water levels reached during highest floods. In the study area, the elevations of the top of the levees along main channel are about 5 metres above AHD for most parts. A 5 metre flood, in the study area, has a return period of 3 years and water levels of highest recorded floods reached up to 8.5 metres above AHD.

The levees of the study area are dominantly composed of fine to very fine sands and with almost no muds. In fluviatile literature, variable sediment composition of levees has been described. Kumar and Singh (1978) identified alternating layers of sand and mud as the sedimentary composition of levees of meandering rivers. Farrell (1987) on the other hand, described levees of a meandering channel to be composed of silty sand mainly and no muds. Smith (1983) found levees of anastomosed channels being made up of dominantly sandy silt, with small proportions of pure sand and no mud.
Fig. 6.1: Sediment characteristics of longitudinal sections of levees along main channel (A) in the Grafton and (B) in Tucabia and Calliope floodplains. See figure 3.3 and 3.5 in chapter 3 for locations of holes in the Grafton and Tucabia floodplains respectively. Bracketed numbers in italics are hole top elevations in metres above AHD.
Fig. 6.2: Sediment characteristics of longitudinal sections of levees along (A) the main channel and (B) the South Arm. See figure 3.9 of chapter-3 for location of holes. Bracketed numbers are hole-top elevations in metres above A.H.D.
Fig. 6.3: Sediment characteristics of levees along left straight channel of the straight channel zone of the Tucabia floodplain. For location of holes see figure 3.6 of chapter 3. Bracketed numbers in italics are hole-top elevations in metres above AHD.
Fig. 6.4: Sediment character of levees along right single straight channel of the straight channel zone of the Tucabia floodplain. For location of holes see figure 3.6 of chapter 3. Bracketed numbers in italics are hole-top elevations in metres above AHD.
Fig. 6.5: Sediment characteristics of levees along the straight channel zone of the Calliope floodplain. For location of holes see figure 3.8 of chapter-3. Bracketed numbers are hole-top elevations in metres above AHD.
Fig. 6.6: Sediment characteristics of levees along (A) distal straight channel zone of the Woodford floodplain, (B) left and (C) right levees of the sinuous channel zone of the Grafton floodplain. See fig.3.9 and 3.4 in chapter 3 for locations of holes in the Woodford and Grafton floodplains respectively. Bracketed numbers in italics are hole-top elevations in metres above AHD.
7. Morphostratigraphy of Plains

7.1: Introduction:

Plains generally have flat surfaces that usually slope downwards, very gently towards the valley margin or away from the adjacent channel. Normally, individual plain elements are elongated geomorphic units with bordering levees. Within the study area, plains occur in five geomorphic zones, (i) adjacent to the main channel or its levees (ii) in point-bar plains (where they are referred to as platforms) (iii) within straight channel zones (iv) within sinuous channel zones and (v) in distal regions of the floodplains.

7.2: Dimensions and elevations:

Plains within the study area can be 100's of metres wide and several kilometres long. The plains along the main channel are generally wider than most of those within floodplain-channel zones. Most of the plains adjacent to the main channel are about 800 metres to a kilometre (Figs.2.4, 2.5, 2.6 and 2.7) wide whereas the widths of the majority of those within the floodplain-channel zones are about 200 to 500 metres wide (Figs.2.13, 2.14, 2.15, 2.19 and 2.20). The elevations of the upper surfaces of the plains are generally around 2.5 to 3.5 metres above AHD. Upper surfaces of the plains along the main channel are generally higher than those within floodplain-channel zones. Plains along the main channel cover only a small fraction of the total area of the Clarence floodplain (Figs.2.4, 2.5, 2.6 and 2.7) while in the case of the floodplain-channel zones, most of the area of their floodplain is covered by plains (Figs.2.13, 2.14, 2.15, 2.19 and 2.20). The dimensions of the plains within floodplain-channel zones are related to the size of the channel zone itself. For example, the plains within sinuous-channel zones of the Tucabia-Calliope floodplain are only about 100 to 150 metres wide for most part (Fig.2.20) whereas plains within a similar type of channel zone on the Grafton floodplain are in places up to a kilometre or more wide (Fig.2.19). For the most parts, the meandering channel zone on the Grafton floodplain is several times wider than equivalent units on the Tucabia-Calliope floodplain. Size of plains can also vary between straight channel zones. The plains of the Calliope (Fig.2.13) or Tucabia (Fig.2.14) straight channel zones are generally wider and longer than those of the Woodford
floodplain (Fig.2.15). However, the plains within straight channel zones of the Tucabia and Calliope areas are similar in size, and the size of these channel zones are also comparable (Fig.2.13 and 2.14). In some parts of the plains along the main channel, the distal margins can have protruding configurations (Fig.2.5). This is due to the presence of crevasse channels within these plains. Present surface configurations of these channels are, however, very shallow and wide and the areas covered by these channels have an overall flattish top. Plains in the distal regions of the floodplains occur only in the Calliope floodplain (Fig.2.6). These plains are formed by the interactions of the straight and meandering channel zones in the distal parts of the Calliope floodplain.

7.3. Sediment characteristics: 

Plains are composed of poorly sorted very fine sands and sandy muds (see figures 7.1 to 7.5). Grain size analysis of representative sediment samples of plains were done and the results are given in table 3.1 and figure 3.11. In most of the plains, very fine sands and sandy muds occur in nearly equal proportions. However, in some cases, clear dominance of one or the other type of these sediments can be observed and rarely, plains can also be entirely composed of either sandy muds or very fine sands. Plains proximal to the main channel tend to be coarser in grain size than those distal in the floodplains (see holes of the Calliope floodplain in figure 7.1).

Thicknesses of plain sediment bodies are generally about 2 to 3.5 metres (see figures 7.1 to 7.5). Plains along the main channel are generally thicker (about 3 metres, figures 7.1 and 7.2) than those within the floodplain-channel zones (mostly about 2.25 metres, figures 7.2, 7.3 and 7.4). Bottoms of the plain sediment bodies outside the floodplain-channel zones occur at greater depths than those within these zones. For the former category of plains, the bottoms generally occur one or two metres below AHD (Figs.7.1 and 7.2), while bottoms of the plains within floodplain-channel zones occur few to several tens of centimetres above AHD (Figs.7.2, 7.3 and 7.4). Splay sediments occur within plain sediments at some locations (e.g. hole PT1 of figure 7.1, hole PW1 of figure 7.2). These splay deposits are identified by their coarser sediments, which are generally better sorted than rest of the plain sediments. These sediments constitute only a
small part of the sediment sequences of the plains. The plains within the sinuous channel zone of Tucabia-Calliope floodplain are exceptional in that they are composed of only sandy muds (hole PU21 of figure 7.5). Plains in some parts of the straight channel zone of the Calliope floodplain are relatively more sandy (section PU4 - PU18 of figure 7.4) than other plains within the study area. However, other than the plains of the sinuous channel zone of Tucabia-Calliope floodplain, there are no significant differences in sediment compositions of plains of other geomorphic zones within the floodplain of the study area.

7.4: Genetic units underlying plains:

Plains of the study area are mostly directly underlain by swamps or sediments of lateral accretion. Underlying swamp units are of quite common occurrence for plains along the main channel (Figs.7.1 and 7.2), whereas lateral-accretion deposits occur underneath most plains in the floodplain-channel zones (Figs.7.3, 7.4 and 7.5). In some cases, plains along the main channel are directly underlain by sediments of estuarine origin (see holes of Tucabia floodplain in figure 7.1 and holes PW1 and PW2 of figure 7.2). The swamp sediments are identified by their finer texture than those of the plains. Swamp sediments are characteristically composed of muds with no sand in them. The lateral-accretion deposits are identified by their moderately sorted dominantly medium sand texture. Texturally estuarine sediments are similar to those of swamps, that is composed of muds, but these have characteristic mollusc and brackish microfauna.

7.5: Discussion:

The presence of swamp deposits and absence of any lateral-accretion sediments underneath the plains along the main channel relates to the lateral stability of the main channel. The lateral-accretion deposits underlying the plains of the floodplain-channel zones indicate that there has been lateral shifting of the prominent channels within these channel zones or there are buried chute channels underlying these plains.

The sediment composition (which is entirely sandy mud) of plains within the sinuous channel zone of the Tucabia-Calliope floodplain is related to the fact that this
channel zone drains the distal swamps of the floodplain and the smaller catchment immediately bordering the floodplain.

The preservation potential of plain sediments is high. Except for localised crevassing, within sediment sequences of the vast majority of plains, there is no evidence of any erosion. Therefore, in case of burial, these plain deposits are expected to be well preserved and their morphologies retained.
Fig. 7.1: Sediment characteristics of plains (outside flood channel zones) of (A) the Grafton, (B) Tucabia and (C) Calliope floodplains. For location of holes see figures 3.3, 3.5 and 3.7 in chapter 3 for the Grafton, Tucabia and Calliope floodplains respectively. Bracketed numbers in italics are hole top elevations in metres above AHD.
Fig. 7.2: Sediment characteristics of plains (A) outside floodplain channel zones and also (B) within the distal straight channel zone of the Woodford floodplain. For location of holes see figures 3.9 and 3.10 in chapter 3. Bracketed numbers in italics are hole-top elevations in metres above AHD.
Fig. 7.3: Sediment characteristics of plains within the straight channel zone of the Tucabia floodplain. For location of holes see figure 3.6 of chapter 3. Bracketed numbers in italics are hole-top elevations in metres above AHD.
Fig 7.4: Sediment characteristics of plains within the straight channel zone of the Calliope floodplain. For location of holes see figure 3.8 in chapter-3. Bracketed numbers in italics are hole-top elevations in metres above AHD.
Fig. 7.5: Sediment characteristics of plains within sinuous channel zones of (A) the Grafton and (B) Calliope floodplains. For locations of holes see figures 3.4 and 3.7 in chapter-3. Bracketed numbers in italics are hole-top elevations in metres above AHD.
8. Morphostratigraphy of Swamps

8.1: Introduction:

Swamps occupy the lowest lying areas of floodplains of the Clarence River, with surfaces that are featureless with little or no relief. Tops of the swamps generally have a centripetal dip but they can also be nearly flat or slightly tilted towards the valley margin. In planview, outlines of swamps are often irregular and these geomorphic units can occur both in the proximal and distal parts of the floodplains. Within the study area swamps occur in three geomorphic zones, (i) outside floodplain-channel zones (ii) within straight channel zones and (iii) within sinuous channel zones.

8.2: Dimensions, spatial distributions and elevations:

Swamps within the study area can be 100's of metres to several kilometres in lengths and widths. Generally swamps within the floodplain-channel zones are much smaller, generally about a few 100's of metres in dimension (Figs. 2.13, 2.14 and 2.19), than those outside which are normally several kilometres in lengths and widths (Figs.2.4, 2.5 2.6 and 2.7). Swamps occur between the main channel and a floodplain-channel zone or between two floodplain-channel zones as in the Calliope floodplain (Fig.2.6). Also swamps may cover major parts of a floodplain segment, as in the Tucabia floodplain (Fig.2.5); where swamp units extend from the area immediately adjacent to the proximal plain along the main channel, to the valley margin, which is several kilometres away from the main channel. These swamps on the Tucabia floodplain are the largest of the study area and bear special implications for the sedimentation modelling of the floodplains of the study area. Swamps within floodplain-channel zones, generally occur between two prominent channels (e.g. see figure 2.13). Elevations of the tops of the swamps generally vary between 0.5 to 1.5 metres above AHD. Surfaces of swamps within floodplain-channel zones are often slightly higher (elevations of 1.5 metres, figures 8.2 and 8.3) than those outside (elevations mostly less than 1 metre, figure 8.1).
8.3. Sediment characteristics:

Swamps are dominantly composed of muds (Figs. 8.1, 8.2 and 8.3). Grain size analysis of representative samples of swamp sediments were conducted and results are given table 3.1 and figure 3.11 in Chapter 3. Generally swamps outside the floodplain-channel zones are almost entirely composed of muds (Fig.8.1) whereas swamps within these floodplain-channel zones have considerable proportions of fine to very fine sands in their sediment sequences (Figs. 8.2 and 8.3). Swamps outside the floodplain-channel zones in the Woodford floodplain and in the distal parts of the Calliope floodplain have some sands in their sediment sequences (Fig.8.1). These sands within the muds of the swamp sediment sequences are mostly interpreted as splay deposits (Figs. 8.1 8.2 and 8.3). Swamps outside the floodplain-channel zones of the Grafton and Tucabia floodplains are entirely composed of muds (Fig.8.1). There is no significant difference between the sediment characteristics of the swamps within straight channel and sinuous channel zones (Figs. 8.2 and 8.3). The bottoms of the swamp sediment bodies generally occur at around 1.5 to 2 metres below AHD (Fig.8.1) and the thicknesses of these units are generally about 2 to 3 metres. Estuarine deposits directly underlie the swamp deposits (Fig.8.1). Both swamp and estuarine deposits are composed of muds but sediments of estuarine deposits are identified by their characteristic molluscs and microfauna.

8.4. Discussion:

Muds throughout the sediment sequences of swamps outside the floodplain-channel zones in the Grafton and Tucabia floodplains (Fig.8.1) are indicative of continuous vertical sedimentation at these localities on the floodplains since the termination of the estuarine phase. Presence of splay deposits in sediment sequences of swamps of the Woodford floodplain and those within the floodplain-channel zones are indicative of chute-channel activities at those parts of the floodplain. The floodplain-channel zones themselves are mostly high-energy chute or crevasse-channel areas.

The size, spatial distribution and sediment characteristics of swamps on the Tucabia floodplain are significant in assessing important sedimentation processes and
history of lateral stability of the main channel within the floodplain of the study area. These swamps, which extend from their channelward border with the plains along the main channel in the proximal part of the floodplain, to the valley margin, several kilometres away (Fig.2.5), and which are composed exclusively of muds (Fig.8.1), represent continuous vertical sedimentation throughout the present fluvial regime. Absence of any lateral-accretion deposits underneath these swamps also indicates that these vast areas of the floodplain were never traversed by the main channel. This in turn, reflects the lateral stability of the main channel. These swamps of the Tucabia floodplain are the largest within the study area and cover extensive areas of the floodplain. The scales of these swamps along with their sediment characteristics indicate that one of the principal modes of sedimentation within the floodplain, was vertical accretion. In the Calliope floodplain, swamps occur in the proximal part of the floodplain immediately next to the plains along the main channel. These swamps are also composed almost entirely of muds (Hole SU7 in figure 8.1). The geographic locations of these swamps and their sediment characteristics also point to the lateral stability of the main channel.

The preservation potential of swamp deposits is high. In most of the large swamps within the study area (that is those outside the floodplain-channel zones), only vertically accreted muds have been deposited and preserved after subsequent burial. However, in most of sediment bodies of swamps within the floodplain-channel zones, contain sediments of splay. This reflects episodic erosion and secondary deposition of coarser (sandy) materials within the muddy sediment sequences of these swamps. These coarser materials, in turn, are also buried by muds of vertical accretion leading to preserved sequences of dominantly muds with zones of sandy sediments.
Fig.8.1: Sediment characteristics of swamps (outside floodplain channel zones) of (A) the Grafton (B) Tucabia (C) Calliope and (D) Woodford floodplains. For location of holes see figures 3.3, 3.5, 3.7 and 3.9 of chapter 3 for holes of the Grafton, Tucabia, Calliope and Woodford floodplains respectively. Bracketed numbers in italics are hole-top elevations in metres above AHD.
Fig. 8.2: Sediment characteristics of swamps within straight channel zone of (A) the Tucabia and (B) Calliope floodplains. See figures 3.6 and 3.8 in chapter 3 for locations of holes in the Tucabia and Calliope floodplains respectively. Bracketed numbers in italics are hole-top elevations in metres above AHD.

Fig. 8.3: Sediment characteristics of swamps within the sinuous channel zone of the Grafton floodplain. For locations of holes see figure 3.4 in chapter 3. Bracketed numbers in italics are hole-top elevations in metres above AHD.
9. Morphostratigraphy of Floodplain Channels

9.1: Introduction:

There are three types of channels within the floodplain of the study area. These are (i) multichannels, (ii) single straight channels and (iii) sinuous channels. Multichannels include convergent splay streams, bifurcating or converging channels, which are often leveed. The sinuous channels include an anabranched branch of the Clarence River, and distal tributary systems. Although the floodplain channels are quite prominent and have well developed floodplains themselves, they are activated only during major floods, in that they provide alternative floodwater pathways, but have the form of chute channels (straight; fed through levee crevasse or convergent crevasse splay). They show a pattern of successive formation, with each new complex capturing flood flow from previous chutes. In this respect, the floodplain channels of the Clarence are different from braided and / or anastomosed floodplain channels described by Nanson et al. (1986), Rust and Nanson (1986) and Nanson et al. (1988) in anastomosed river systems of semi-arid regions of Australia, and are different from back channels along the distal part of floodplains described by Nanson (1986) and Croke (1991).

9.2: Surficial morphology:

9.2.1: Multichannels:

These are channels with multiple small channels, ridges and platforms nested within a broader tract of channel deposits. These are wider than any other channels on the floodplain and roughly straight in plan view (Figs. 2.11, 2.12 and 2.15). Maximum width of these channels varies between 700 metres to 1.4 kilometres and can be up to several kilometres in length. Details of parts of these channels of the Tucabia and Calliope floodplains have been shown in figure 9.1. The nested secondary channels are generally between 30 to 50 metres in width. The ridges and platforms have similar surficial morphology as those of the levees and platforms of point-bar plains. Ridges are generally 20 to 30 metres in width and up to 100 to 200 metres in length. Platforms are often a few hundred metres long and generally vary in width from about 50 metres to 200 metres. The ridges are often 0.5 to 1.0 metre higher than the platforms. The banks /
levees along the multichannels are 1 to 1.5 metres higher than the highest points (ridges) within these channels. Widths of multichannels generally decreases downstream, leading eventually, in most cases, to the formation of single channels (Fig.9.1). The multichannel of the Tucabia floodplain, truncate at right angle, the multichannel of the Calliope floodplain, indicating two distinct phases of development of these channels (Fig.9.1), where the flow of the Calliope multichannel, which formed first, was captured by that on the Tucabia floodplain.

Apart from the multichannels described above, there are multichannel areas within the floodplain, where a number of parallel to semi-parallel straight channels occur; but unlike the multichannels, are not nested within a broader channel. Ridges and platforms also occur within these channel areas. The channels are generally 20 to 30 metres wide and a few hundred metres long. The ridges are developed in some parts along the channels and often between two adjacent channels. The platforms occur in areas where any two channels are some distance apart, and are generally flat lying areas. Ridges are higher than the platforms by about half a metre. These channel areas occur in the proximal part of the Woodford floodplain (Fig.2.7), within the sinuous channel zone of the Grafton floodplain (Fig.2.18) and within the straight channel zone of the Calliope floodplain (Fig.2.14). Multichannel areas, which are parts of the of straight channel zone of the Calliope floodplain, have been identified as its flood-channel zone (Fig.2.14).

9.2.2 : Single straight channels :

Single straight channels are straight to slightly sinuous and occur within the straight channel zones of Tucabia (Fig.2.11) and Calliope (Fig.2.12) floodplains. The length of these channels can be up to several kilometres but their maximum width is only about 160 metres. All these channels generally become narrower downstream and eventually pinch out. These channels are associated with multichannels at the upstream end (Figs.2.11 and 2.12).

9.2.3 : Sinuous channels :

These are sinuous single channels within the sinuous channel zones (Figs.2.17 and 2.18) which occur in the Grafton (Fig.2.4) and Calliope floodplains (Fig.2.7). The
sinuous channel on the Grafton floodplain, which is an anabranch of the Clarence, is about 160 metres wide (Fig.2.18); while the distal sinuous tributary of the Calliope floodplain is 80 metres in width (Fig.2.17). Each of these channels are several kilometres long.

9.3 : Sediment character :

9.3.1 : Multichannels :

Sediments of multichannels can be divided into those that were laterally and vertically accreted (Fig.9.2). The results of the grain size analyses of these sediments are included in table-3.1 of chapter 3. Laterally-accreted deposits are almost all medium sands, which are moderately sorted and strongly fine skewed. Vertically-accreted deposits are predominantly fine to very fine sands with muds occurring in some places. These vertically-accreted deposits are moderately to poorly sorted and near symmetrical to strongly fine skewed. Laterally-accreted deposits are mostly about 3 to 4 metres in thickness, whereas sediments of vertical accretion are mostly between 1.5 to 2 metres thick (Fig.9.2). Tops of the laterally-accreted deposits within these multichannels generally occur at about 60 to 70 centimetres above AHD while the bottoms of these deposits, which are also the bottoms of the multichannels, generally occur at depths of 3.5 to 3.7 metres below AHD (Fig.9.2). Secondary elements within these multichannels / multichannels areas; such as ridges, platforms and secondary channels fills, are all parts of vertically-accreted deposits (Figs.9.2, 9.3 and 9.4). Vertically-accreted deposits have been described above.

9.3.2 : Single straight channels :

These are composed of laterally-accreted and channel-fill deposits (Fig.9.5). Laterally-accreted deposits are generally about 2.5 metres thick, whose tops occur mostly about 50 centimetre below AHD. The bottom of these deposits, which are also the bottoms of these channels, occur at about 3.5 metres below AHD (Hole CU 5 of figure 9.5). Lithology of the laterally accreted deposits are the same as those of the multichannels, while channel-fill sediments are poorly sorted, strongly fine skewed very fine sand to muds.
9.3.3. Sinuous channels:

These are also composed of lateral-accrated and channel-fill deposits. The lateral-accretion deposits are about a metre thick and are medium sands of moderate sorting and strong fine skewness. The channel-fill deposits are dominantly muds which are poorly sorted, finely skewed very fine silts.

9.4. Discussion:

Most of the secondary channels within the multichannels of the Tucabia and Calliope floodplains, converge downstream and which have been described as convergent splays (Fig.9.1). This possibly happens due to sediment choking in most parts of the multichannels at their downstream ends. The mechanism can be divided into three phases. Firstly, a large amount of sediments get carried through the multichannel sections to their downstream end, when there is higher energy / velocity available within the channel. Secondly, when energy levels and discharges through these channels drop, these sediments infill most of the areas across these multichannel at their downstream ends, allowing only one or two most prominent channels to flow further downstream. At this stage, several smaller channels converge their courses, upstream of such a point of sediment choking, and merge with the bigger channel(s) which flow(s) further downstream. Rundle (1985) has shown that convergence of a number of channels within a braided channel can take place if the channel is mostly choked at any point. The mechanism of convergence of a number of smaller channels to form a relatively bigger channel, well explains the transformation of multichannels into single straight channels within some of the straight channel zones of the study area.
Fig. 9.1: Details of parts of multichannels of the Tucabia and Calliope floodplains.
(A) Generalised cross-section of multi-channel area of Calloipe Creek system:

(B) Generalised cross-section of multichannel area of Sweneeys Creek system:

Scale: Horizontal: 50 100m Vertical: 0.5 1.0m

Fig.9.2: Generalised cross-sections of multi-channels within straight channel areas of (A) the Calloipe and (B) the Tucabia floodplains. For location of holes see, figure 3.8 for the Calloipe and figure 3.6 for the Tucabia floodplains. Symbols are same as figure 9.3.
Fig. 9.3: Sediment characteristics of channels, ridges and platforms of (A) distal multichannel and (B) proximal multichannel areas of the Woodford floodplain. See figures 3.10 and 3.9 for locations of holes of distal multichannel and proximal multichannel areas respectively.
Fig. 9.4: Sediment characteristics of different geomorphic units of (A) floodchannel area within the straight channel zone of the Calliope floodplain and (B) multichannel area of the sinuous channel zone of the Grafton floodplain. See figures 3.8 and 3.4 for locations of holes of flood channel area of the Calliope floodplain and the sinuous channel zone of the Grafton floodplain respectively.
Fig. 9.5: Sediment character of channels of single straight channels of (A) the Tucabia and (B) the Calliope floodplains. See figures 3.6 and 3.8, for locations of holes within the Tucabia and Calliope straight channel zones respectively.
Fig. 9.6: Sediment character of the sinuous channel of the Grafton floodplain. Legend for genetic facies and texture are same as figure 9.5. For location of holes see figure 3.4.
10. Floodplain-Channel Zones

10.1: Introduction:

Floodplain-channel zones are the most important geomorphic features within the study area (Figs. 2.4, 2.5, 2.6 and 2.7). These are channel and secondary floodplain complexes within broader floodplain of the Clarence River and are formed by major flood channels, either multichannel (splays), straight or sinuous. As shown later, almost all these channel zones are not palaeochannels and floodplains of the main channel of the Clarence River. In the fluvial literature, palaeochannels and anabranches are widely recognised components of floodplains (Fisk, 1944, 1947; Russell, 1954; Coleman, 1969; Jackson, 1978; Carson, 1984) and floodwater chutes are recognised (Schumm and Litchy, 1963; William and Guy, 1973; Baker, 1977, 1988; Gupta, 1983; Kochel, 1988). The morphostratigraphy of composite floodplain-channel zones of the type found on the Clarence floodplains appear not to have been described in fluvial literature.

10.2: Geomorphic description:

There are two types of channel zones within the floodplain of the study area: (i) straight and (ii) sinuous. Straight channel zones are formed by multichannels and single straight channels, while sinuous channel zones are formed by sinuous channels. Each of these channel zones can be subdivided into (i) channel and (ii) floodplain subzones, based on the geomorphology (Figs. 2.8, 2.9, 2.10, 2.16 and 2.17). Each of these subzones are again divisible into different geomorphic units, such as; multichannels, single straight channels, levees, plains etc, each of which has been discussed in different chapters from 6 to 9. Within channel subzones of the straight channel zones, multichannels are located at their upstream part and is followed downstream by single straight channels (Figs. 2.11 and 2.12), which are much narrower than the multichannels. Channels within these channel zones, decrease in width in their downstream direction and, upstream parts are commonly immediately adjacent to the main channel. This reflects gradual decrease of energy levels of these channel zones away from the main channel. This also provides evidence that these floodplain-channel zones are "chute-
type" floodplain channels and floodplains rather than palaeochannels. Sinuous channel zones can be formed by either anabranch or distal floodplain channels, and their dimensions also vary greatly (Figs.2.16 and 2.17). Sinuous channel zones occur in the distal part of the floodplain segments, while the straight channel zones generally occur in their proximal parts (Figs.2.4, 2.5, 2.6 and 2.7). Generally straight channel zones are larger in area than sinuous channel zones. However, the dimensions of these flood-channel zones can vary considerably. These channel zones are generally elongated to slightly sinuous in shape and their dimensions can vary from a few to several kilometres in length and 100's of metres to several kilometres in width (Figs.2.8 to 2.20). Straight channel zones occur in all the floodplain segments except Grafton, while Woodford is the only floodplain segment without a sinuous channel zone (Figs.2.4 to 2.7). The Tucabia and Calliope floodplains share a single sinuous channel zone along their distal parts. This sinuous channel originates at valley marginal swamps of the Tucabia floodplain, traverse several kilometres through the marginal areas of the floodplains and meets the South Arm (the southern branch of the main channel) (Figs.2.5 and 2.6).

Levees within channel zones are best developed along single straight channels (Fig.2.13), and some parts of the sinuous channels (Fig.2.19). Plains are generally more extensive in the straight channel zones (Figs.2.13, 2.14). Occasionally, secondary flood channels may occur within floodplains of straight channel zones (Fig.2.14), indicating relative higher energy levels at the time of formation compared to other channel zones. The anabranch of the present Clarence, which forms the sinuous channel zone on the Grafton floodplain (Fig.2.4), has multichannels near its upstream parts of its channel subzone (Fig.2.18), which indicate a large influx of water from the main channel at the time of flood, similar to the multichannels of straight channel zones. Difference in elevations between the flood-water level within the main channel and the floodplain may have acted as a cause for such an influx flood water into these channel zones.

Spatial distribution of different geomorphic units within channel zones is variable (Figs. 9.1 to 9.7). Channels are generally located at the central parts of the channel zones, which are flanked by plains and levees and occasionally overbank chute
channels (which have been described in this thesis as floodplain channel areas of the channel zones).

One of the important features of the mutual relationship of the channel zones of the Clarence floodplain is that they can truncate one another at right angles, indicating episodic capture of flow from one channel zone to other. This is the case between straight channel zone: of Tucabia and Calliope floodplains (Fig.12.1).

**Table-10.1: Spatial distribution of channel zones in the floodplain segments.**

<table>
<thead>
<tr>
<th>Channel zone</th>
<th>Grafton</th>
<th>Tucabia</th>
<th>Calliope</th>
<th>Woodford</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sinuous</td>
<td>C; D</td>
<td>D</td>
<td>D</td>
<td></td>
</tr>
<tr>
<td>Straight</td>
<td>P</td>
<td>C</td>
<td></td>
<td>P; D</td>
</tr>
</tbody>
</table>

P= Proximal; C= Central; D= Distal;

**Table-10.2: Composition of straight channel zones in different floodplain segments.**

<table>
<thead>
<tr>
<th>Floodplain segment</th>
<th>Single --</th>
<th>Multi --</th>
<th>Ridge --</th>
<th>Platform --</th>
<th>Levee --</th>
<th>Plain --</th>
<th>Swamp --</th>
<th>Flood channel zone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tucabia</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>Calliope</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>Woodford</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td></td>
</tr>
</tbody>
</table>

**Table-10.3: Composition of sinuous channel zones in different floodplain segments.**

<table>
<thead>
<tr>
<th>Floodplain segment</th>
<th>Channel</th>
<th>Multichannel</th>
<th>Plain</th>
<th>Levee</th>
<th>Swamp</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grafton</td>
<td>*</td>
<td>*</td>
<td></td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Tucabia/Calliope</td>
<td>*</td>
<td>*</td>
<td></td>
<td>*</td>
<td></td>
</tr>
</tbody>
</table>

* = Present.

**10.3: Sediment character:**

All the floodplain-channel zones are composed of laterally and vertically accreted deposits (Figs.10.1 to 10.7). Laterally-accreted deposits are all medium sands
which are moderately sorted and generally strongly fine skewed (Table-3.1 in chapter 3). The vertically-accreted deposits are muds, very fine sand and fine sand which are moderately to poorly sorted and near symmetrical to strongly fine skewed (Table-3.1 of chapter 3). The bottom of the laterally accreted deposits which is also the bottom of the channel zones vary between about 2 to 3.5 metres below AHD. These are about 3.5 metres for the straight channel zones of Tucabia and Calliope floodplains (Figs.10.1 and 10.2 for Tucabia straight channel zone, and figures 10.3 and 10.4 for that of the Calliope floodplain). The bottom of the laterally-accreted deposits of the distal straight channel zone of Woodford floodplain occur at depth of about 2 metres below AHD (Fig.10.5). The bottoms of the laterally accreted deposits of the sinuous channel zone of Grafton floodplain vary between 2.5 to 3 metres below AHD (Fig.10.6). The tops of laterally-accreted deposits occur about 30 to 70 centimetres above AHD. The thickness of these deposits within the floodplain-channel zone are generally in the order of 2.5 to 4 metres. The vertically-accreted deposits occurring above those of lateral accretion, are generally 2 to 3 metres thick (Figs.10.1 to 10.7). The depths of the channel zones are much shallower than that of the main Clarence River, which is an indication that these channel zones are very superficial features on the floodplain that were formed by stripping of the estuarine deposits during floods in the Clarence valley.

Laterally-accreted deposits occur under channels (both multichannels and single straight channels) and also in the lower part of the sedimentary sequence of levees and plains immediately adjacent to these channels (Fig.10.1 to 10.7). Presence of laterally-accreted deposits underneath levees and plains in the floodplain-channel zones, is due to the limited lateral shifting of the channels. However, in some swamps, between two single straight channels within the straight channel zone of the Tucabia and Calliope floodplains (Fig.10.2 and 10.4), and in the distal part of the plain within the sinuous channel zone on the Grafton floodplain (Fig.10.6) only vertical accreted deposits constitute the entire sedimentary sequence. In these places the thickness of the vertical accreted deposits can be nearly 5 metres. The vertically accreted deposits of the straight channel zones are dominantly fine to very fine sand (Fig.10.1 to 10.5), whereas these
deposits of the sinuous channel zones are dominantly very fine sands to muds (Figs. 10.6 and 10.7).

The planview presentation of sediment character of different floodplain-channel zones have been made in figures 10.8 to 10.12. In the process of the preparation of these maps, generalised profiles (given in small boxlike figures within figures 10.8 to 10.12) were first made from the representative cross-sections drawn in figures 10.1 to 10.7. Following this, planview representative symbol for each of these profiles were assigned, and these symbols were plotted on the geomorphic maps of floodplain-channel zones. Similar profile type maps have been used to describe deposits of coastal and fluvial origin by a number of workers (e.g. Streif, 1978; Baeteman, 1981).

10.4 : Discussion :

The channel zones of the Clarence floodplain, in their various forms demonstrate the importance of overbank-flood discharges for sculpturing the morphology and depositing tracts of secondary sediments, which are more widespread and diverse than seems to have been recognised elsewhere. The channel zones occupy about 40% of the entire Clarence floodplain, not only are they characterised by the different classes of channels, outlined above, but also have their own systems of levees, platforms /or local, vertically accreted plains, and swamps. Further, the channel zones are activated episodically and rare events of large magnitude have been interposed by relatively more frequent, geomorphologically significant events. For example, multiple subparallel channels of the Calliope straight channel zone are nested between levees and inset into deposits of formerly larger channels that registrar very large, infrequent events; the smaller channels represent subsequent, lesser floods. The largest, or "catastrophic" floods are represented by features such as the sinuous anabranch on Grafton floodplain, the initial formation of large straight channels that subsequently become composites of smaller channels (e.g. multichannels of the Tucabia and Calliope floodplains) and by the redirection of major flows, represented by successive differently directed convergent splays of Calliope and Tucabia multichannels. To some extent, these nested channels and
deposits resemble those which Nanson (1986) described on episodically stripped floodplains. The vertically-accreted sediments of the levee plains, the channel-fills and swamp muds of the floodplain-channel zones represent deposition largely from least energetic and perhaps most frequent floods of the Clarence River.

The sinuous channel zone of the Tucabia-Calliope floodplain is a typical backwater-floodplain channel, draining the distal swampy areas (Fig. 2.5 and 2.6). Similar type of channels have been described by Blake and Ollier (1971) and Kesel et al. (1974) for rivers which have only limited lateral migration, and where valley marginal areas are never affected by the channel migration processes. The sinuous channel zone on the Grafton floodplain is also located in the distal part of the floodplain (Fig. 2.4) but because this channel was connected to the main channel at its upstream end, it acted as a conduit for flood water and also as a minor floodplain distributary. Therefore, it had better scope to build its floodplains (what is presently seen), and as a result, the floodplain of this channel zone (Fig. 2.4 for location of the channel zone and figure 2.16, 2.18 and 2.19 for detail geomorphology of the channel zone) is much wider than that of the Tucabia-Calliope floodplain (Fig. 2.5 and 2.6 for location of the channel zone and figures 2.17 and 2.20 for detail geomorphology of the channel zone). The presence of a multichannel area within the channel subzone of this sinuous channel zone (Fig. 2.18) indicates that it carried unusually larger discharge during times of high flood.

The presence of sandy muds as the only constituent of the vertical-accretion deposits of the sinuous channel zone of Tucabia-Calliope floodplain (Fig. 9.7) is related to its location within the floodplain. It drains the swamps which are composed of muds, and also located at a great distance from the main channel, where coarser sandy sediments seldom travel. The channel within the sinuous channel zone of Grafton floodplain has metres of muds as its channel-fill deposits. Silts and clays as abandoned channel-fill deposits have been widely mentioned in fluvial literature (such as Fisk, 1944, 1947; Glenn and Dahl, 1959; Bernard et al., 1962; Bernard and Major, 1963).

Smith et al. (1989) while describing avulsion history of a sand dominated Canadian river, identified three stages of splay evolution. Stage-I splays are small, lobate
shaped and crossed by a number of unstable distributary channels. Stage-II of these splay, which evolve from Stage-I splays, contain a number of anastomosed channels; but the number of these channels are much less than those of Stage-I splay. Stage-III may evolve from both Stage-I or II, and this has only a few channels, and due to the high rate of channel abandonment, flow may be eventually concentrated into a single channel. Smith et al. (1989) called these stages of splay as (i) initial avulsion stage (ii) anastomosed stage (iii) reversal stage (from a higher number of channels of initial crevassing to less but well established anastomosed channels) and (iv) single channel stage. The straight channel zones of the Tucabia and Calliope floodplains have possibly undergone similar evolution as mentioned above, although there has not been any avulsion of the main channel in this case. The multichannel areas at the upstream part of the straight channel zones are possibly representative of Stage-I of Smith et al. (1989). The single straight channels at the downstream end of the multichannel areas also possibly represent Stage-III. There is no distinct Stage-II for these channels of the Clarence floodplain. Transformation from Stage-I to Stage-III takes place through channel convergence at the downstream end of the multichannel areas, and single straight channels are formed. However, the most important message that comes out of Smith et al. (1989) findings is that, if the crevasse splay are activated several times, they will evolve over time, and eventually form long and single channels; that is how the straight flood-channel zones of the Tucabia and Calliope floodplains are inferred to have been formed. The proximal straight channel zones of the Woodford floodplain (Fig.2.7) represent Stage-II of the above mentioned mechanism. The distal straight channel zone of Woodford floodplain is one of chute-channel type. This is inferred, because there is no well developed levees along this channel, and the banks are much less conspicuous than those on the straight channels of Tucabia or Calliope floodplains. It is quite obvious that chute channels may develop at this part of the floodplain during high floods, because the marginal hills are almost at right angle to the flow of the South Arm (Fig.2.3 for location of the Woodford floodplain and figure 2.7 for location of the distal straight channel zone), which flows through a narrow gap within the marginal hills.
Sand dominated deposits of different forms of crevasse splays have been described among others by Friend et al. (1979) and O'Brien et al. (1986) and those of anastomosed channel deposits have been described among others by Smith and Smith (1980), Smith (1986), Walker and Cant (1984) and Miall (1985).
Fig. 10.1: Generalised cross section and sediment character of multichannel zone of the straight channel zone of the Tucabia floodplain. For location of the straight channel zone within the floodplain segment, see figure 2.5. For planview of geomorphic units of the channel zone, see figure 2.8, 2.11 and 2.13. For location of holes see figures 3.6.
Fig. 10.2: Generalised cross section and sediment character of single straight channel area of the straight channel zone of the Tucabia floodplain. For location of the channel zone within the floodplain segment, see figure 2.5. For planview of the geomorphology of the channel zone, see figure 2.8, 2.11 and 2.13. For location of holes see figure 3.6.
Fig. 10.3: Generalised cross-section and sediment character of multichannel zone of the straight channel zone of the Calloppo floodplain. For location of the straight channel zone within the floodplain segment, see figure 2.6. For planview of the channel zone, see figure 2.9, 2.12 and 2.14. For location of holes see figure 3.8.
Fig. 10.4: Generalised cross section and sediment character of single straight channel area of the straight channel zone of the Calliope floodplain. For location of the channel zone within the floodplain segment, see figure 2.6. For planview of geomorphic features of the channel zone, see figures 2.9, 2.12 and 2.14. For location of holes see figure 3.8.
Fig. 10.5: Generalised cross section and sediment character of the distal multichannel of the Woodford floodplain. For location of the channel zone within the floodplain segment, see figure 2.7. For planview of geomorphic features see figure 2.15. For location of holes see figure 3.10.
Fig. 10.6: Generalised cross section and sediment character of the sinuous channel zone of the Grafton floodplain. For location of the channel zone within the floodplain segment, see figure 2.4. For planview of geomorphic features see figure 2.19. For location of section and holes see figure 3.4.
Fig. 10.7: Generalised cross-section and sediment character of the sinuous channel zone of the Tucabia-Calliope floodplain. For location of the channel zone within the floodplain segment, see figure 2.5 and 2.6. For planview of geomorphic features, see figure 2.20. For location of holes see figure 3.7. The index of this figure is same as those of figure 10.6.
Fig. 10.8: Profile type map of the straight channel zone of the Tucabia floodplain. Generalised profiles have been made from cross sections in figure 10.1 and 10.2.
Fig. 10.9: Profile type map of the straight channel zone of the Calliope floodplain. Generalised profiles have been made from cross sections in figures 10.3 and 10.4. Textures of sediments are same as those of figure 10.8.
Fig. 10.10: Profile type map of the distal straight channel zone of the Woodford floodplain. Generalised profiles have been made from cross sections in figure 10.5.
Fig. 10.11: Profile type map of sinuous channel zone of the Grafton floodplain. Generalised profiles except for multichannel area have been made from figure 10.6. Profile for the multichannel area have been drawn from section B of figure 9.4.
Fig. 10.12: Profile type map of the sinuous channel zone of the Tucabia-Calliope floodplain. Generalised profile have been developed from figure 10.7.
11. Floodplain Segments

11.1: Introduction:

Floodplain segments are subdivisions of the floodplain of the study area. The criteria for this division are (i) geographic location relative to the main channel and (ii) geomorphic characteristics which are dominated by the types and spatial distributions of the different floodplain-channel zones. Geomorphic and sedimentary characteristics of the different floodplain segments are sufficiently variable to justify subdivisions. The main channel within the study area is laterally stable but unlike most of the floodplains of the laterally stable channels (such as anastomosed channels), the Clarence floodplain is geomorphologically and sedimentologically complex and variable in its different segments. Therefore, investigation of geomorphology and sediment characteristics at the scale of the floodplain segments is important to an understanding of the forms and processes operative within the floodplain of the study area.

Floodplains segments are located on either side of the main channel; they have variable shape and extension, up to kilometres in dimension and may have common boundaries between any two of them. The floodplain segments that were investigated, from the upstream end of the river, are Grafton, Tucabia, Calliope and Woodford (Fig.2.3). Of these, only the Grafton floodplain is located on the left (north) bank of the main channel and the rest are on the opposite side. Tucabia and Calliope floodplains share a common boundary between them whereas the others are separated by either the main channel or its South Arm (Fig.2.3). These floodplains are elongated to semicircular in shape and extend both longitudinally and laterally (Fig.2.3).

Geomorphic compositions of floodplain segments are complex. They consist of various types of channels, ridges, platforms, levees, plains and swamps (described in Chapters 6 to 10). Some of these geomorphic elements are genetically related to the main channel, while others owe their origin to the various floodplain channels (described in Chapter 9) and form floodplain-channel zones (described in Chapter 10), that have no direct relationship with the main channel. The distribution of different geomorphic
features in floodplain segments has been shown in figures 2.4, 2.5 2.6 and 2.7 in Chapter 2.

Floodplain-channel zones are the most striking features within the segments of the floodplain of the study area. From upstream to downstream of the floodplain, there is a progression in the pattern of channels, from relatively few subsidiary channels of simple form, to complexes of multiple subsidiary channels. Upstream, the few secondary channels are anabranches and floodwater distributaries feeding back-plain swamps (sinuous channel zone of the Grafton floodplain); downstream, the straight channel complexes (in the Tucabia, Calliope and Woodford floodplains) are multiple chute and splays of complex form and a history of flow capture.

Table - 11.1: Geomorphic composition of different floodplain segments.

<table>
<thead>
<tr>
<th>Name of geomorphic units</th>
<th>Grafton --</th>
<th>Tucabia --</th>
<th>Calliope --</th>
<th>Woodford</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ridge</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Platform</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>Levee</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Plain</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Swamp</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Channel zone</td>
<td>M, S</td>
<td>M, S</td>
<td>M, S</td>
<td>S</td>
</tr>
</tbody>
</table>

M= Sinuous channel zones; S= Straight channel zone; * = Present.

11.2 : Grafton floodplain : 

Grafton floodplain is dominated by a sinuous channel zone (Fig.2.4). This is a former anabranch which today carries flood overflows into distal parts of the floodplain. Limited migration of this anabranch within its channel zone is indicated in the subsurface by a proximal body of medium sand which is interpreted as a lateral-accretion deposit, and this in turn is buried by vertical floodplain levee and plain sediments (see sediments of sinuous channel zone in figure 11.1). The main channel appears to have remained almost stationary except at the downstream margin of the
floodplain segment, where the Southgate point-bar plain indicates limited lateral migration (Fig.2.4). Between the main and the former anabranch channel (which formed the sinuous channel zone), vertical sedimentation (see sediments of swamps and plains of the Grafton floodplain in figure 11.1) persisted since termination of the Holocene estuarine phase (Estuarine deposits and Holocene evolution of the floodplains are described in Chapter 4) giving rise to the plains and swamps of the present Grafton floodplain. The planview of the sediment distribution of the Grafton floodplain is presented in figure 11.6. A sedimentation model of the Grafton floodplain is shown in figure 11.10. This model suggests that the proximal and central parts of the floodplain have been developed through continuous primary vertical sedimentation (phase V-1), since the termination of the estuarine phase, while the distal part of the floodplain has formed by the secondary lateral (phase L-2) and vertical (phase V-3) accretion. Primary vertical sedimentation is related to the main channel etc. whereas secondary sedimentation is related to the deposition within floodplain-channel zones.

11.3: Tucabia floodplain:

Tucabia floodplain is dominated by swamps (Fig.2.5). At the upstream part of the floodplain, these swamps extend from its proximal part, from the outer margin of the plains along the main channel, to the valley margin which is several kilometres away (Fig.2.5). Since the termination of the estuarine phase, the main channel has remained laterally stable and these parts of the Tucabia floodplain have developed by vertical accretion only (Fig.11.2). At the downstream part of the floodplain, a straight channel zone occurs which also covers a substantial part of this floodplain (Fig.2.5). This channel zone has multiple channels at its upstream end, which look like splays and these multiple channels converge downstream to form single straight channels (channels and channel zones of the floodplain have been described in Chapters 9 and 10 respectively). Channels within these channel zones had limited lateral migration which is indicated in the subsurface by the presence of a body of medium sands that are interpreted as lateral-accretion deposits, and these are, in turn, buried by levee and plain sediments (see straight channel zone in figure 11.3). The planview of sediment distribution for the
Tucabia floodplain segment is given in figure 11.7. Two sedimentation models can be built for the Tucabia floodplain. In the first of these (Fig.11.11), there has been one continuous vertical sedimentation phase (phase V-1) ever since the termination of the estuarine phase, which has formed levees and plains along the main channel and swamps in the rest of the upstream part of the Tucabia floodplain. In the second model (Fig.11.12), the deposits of initial vertical accretion (phase V-1) are eroded in some parts of the floodplain by the straight channel zone, and the floodplain in this part is developed by secondary lateral and vertical accretion within this channel zone. Secondary sedimentation is related to the processes within the channel zones only and has no direct process relationship with the main channel.

11.4: Calliope floodplain:

Most parts of the Calliope floodplain are covered by a straight channel zone which is located at its central part (Fig.2.6). Similar to the channel zone of the Tucabia floodplain, this channel zone also has multiple channels at the upstream, and a single straight channel zone at the downstream part (for a detail description of these channel zone see Chapters 9 and 10). However, the length of the multiple channel part of the straight channel zone is much longer than that of the Tucabia floodplain and also the number of channels is much greater. This channel zone has a similar pattern of sedimentation (Fig.11.4) to that of the Tucabia floodplain (Fig.11.3). There is also a sinuous channel zone in the distal part of this floodplain which is relatively much narrower than the straight channel zone. The sedimentation pattern of this channel zone is the same as that of the straight channel zone (Fig.11.4). The area between the main channel and the straight channel zone is covered by levee, plain and swamps (Fig.2.6), which are all vertically accreted (Fig.11.4), and this process has been going on since the termination of the estuarine phase; this suggests lateral stability of the main channel. Swamps and plains also occur between the straight and sinuous channel zones in the distal part of the floodplain (Fig.2.6) and these are also vertically accreted (Fig.11.4). The planview of sediment distribution in the Calliope floodplain is given in figure 11.8 and its sedimentation model is given in figure 11.13. The latter is similar to the
sedimentation model of the downstream part of the Tucabia floodplain. Main elements of the model are; (i) lateral stability of the main channel, (ii) vertical sedimentation in the proximal and distal parts of the floodplain and (iii) secondary lateral and vertical sedimentation in the floodplain-channel zones which cover other parts of the floodplain segment.

11.5 : Woodford floodplain :

Straight channel zones make up substantial parts of the Woodford floodplain although swamps are also quite extensive (Fig.2.7). However, most of the proximal and central parts of the floodplain are covered by the marginal levee, plain and swamps which are mostly vertically accreted indicating lateral stability of the main channel (Fig.11.5). However, minor localised lateral migration of the main channel has resulted in the formation of a subsurface body of medium sand which is interpreted as a laterally-accreted deposit and which is, in turn, buried by vertically accreted levees. Unlike the straight channel zones of any other floodplain, the straight channel zone in the distal part of this floodplain is composed of multichannels throughout its entire length; this is a reflection of the complex channel activities in this floodplain. The sedimentation pattern within this channel zone is broadly similar to that of the channel zones of any other floodplain (Fig.11.5). The planview of the sediment distribution is presented in figure 11.9 and the sedimentation model is presented in figure 11.14. These are similar to that of the Calliope (Fig.11.13) or that of the downstream part of the Tucabia floodplain (Fig.11.12), where continuous vertical sedimentation since the termination of the estuarine phase is going on in all parts of the floodplain except the floodplain-channel zones, where secondary lateral and vertical accretion have built these channel zones.

11.6 : Discussion :

The main channel within the study area is laterally stable (shown by the sedimentation models of floodplain segments in figures 11.10 to 11.14) and since the termination of the estuarine phase, vertical sedimentation from overbank flooding has been going on in all parts of the floodplains except those covered by the floodplain channel zones. In the floodplain-channel zones (which cover about 40% of the Clarence
floodplain), sediments were deposited by secondary lateral and vertical accretion. Therefore, within the floodplain of the study area, two broad modes of floodplain accretion can be identified, (i) vertical accretion and (ii) floodplain-channel zone accretion. In some areas within the floodplain, vertically accreted plains and swamps make up major parts of the floodplain segment (as in Tucabia floodplain, see figure 2.5). In most other places, floodplain-channel zones cover most areas. Therefore, it can be stated that the floodplain-channel zones and their sedimentation patterns are important geomorphic and sedimentation units within the floodplains of this study area.
Fig. 11.1: Representative lateral cross section of the Grafton floodplain.
Fig. 11.2: Representative lateral cross section of upstream part of the Tucabia floodplain.
Fig. 11.3: Representative longitudinal cross-section of the Tucabia floodplain.
Fig. 11.4: Representative lateral cross section of the Calliope floodplain.
Fig. 11.5: Representative lateral cross section of the Woodford floodplain.
Fig. 11.6: Plan view of sediment distribution of the Grafton floodplain. Primary deposits are related to the main channel while secondary deposits are formed by the floodplain channel zones.
Fig. 11.7: Planview of sediment distribution of the Tucabia floodplain. Primary deposits are genetically related to the main channel while secondary deposits are related to the floodplain channel zones.
Fig. 11.8: Planview of sediment distribution of the Calliope floodplain. Primary deposits are genetically related to the main channel while secondary deposits to the floodplain channel zones.
Fig. 11.9: Planview of sediment distribution of the Woodford floodplain. Primary deposits are related genetically to the main channel while secondary deposits are related to the floodplain channel zones.
Fig. 11.10: Sedimentation model of the Grafton floodplain.
Fig. 11.11: Sedimentation model of the upstream part of the Tucabia floodplain.
Fig. 11.12: Sedimentation model of longitudinal section of the Tucabia floodplain.
Fig. 11.13: Sedimentation model of the Calliope floodplain.