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Article

Seasonal Patterns of Sediment Supply to Coastal Foredune of Seungbong Island, Korea

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Abstract : The seasonal patterns of sediment supply were investigated during the period of June 1999 to June 2000 on a coastal foredune of Seungbong Island, Korea. Sediment supply was determined from measurements of geomorphic changes in the foredune and beach along six lines. Most sands were deposited on the dunefoot and foredune area during the winter and spring, from November to April. The largest amount of sands was deposited along the lines 5 and 6 near the sea-dike in the southern tip of the dune area. In general, the sand on the beach was gradually eroded in spring, summer and fall but deposited in winter. Total sediment accumulation over the study period was 484 m^3 for the foredune and 345 m^3 for the beach. The volume of the foredune increased in the winter and spring, whereas the volume of beach increased in the winter. Variation in sediment deposition appears to be controlled primarily by variations in the seasonal wind regime.

Key words : coastal foredune, geomorphic change, wind, sediment accumulation.

1. Introduction

The coastal area is composed of shoreface, beach, and coastal dune. Coastal dunes are formed along the coastline where there is a large amount of sand supply and a favorable wind regime. Longshore currents transport the sand to the shoreline and waves deposit the sand on the beach. The winds at low tide then transfer the sand grains from the beach to the dune. An additional major source of dune sand is storm overwash deposition (Leatherman 1979).

In broad terms, the processes of vegetated foredune formation are controlled by several physical and biological factors: wind flow, littoral sediment supply, vegetation, topography, grain size, etc. (Short and Hesp 1982; Pye 1982, 1983; Psuty 1988). Willetts (1989) proposed the conceptual model for the development of vegetated dune. The three main factors for dune formation are wind flow, vegetation, and topography. Many of these factors are not separate entities but are inter-related. Wind transports sand grains from the beach to the dune. The wind flow influences topographic changes and vegetation types and densities. The sediment supply determines the scale of dune and controls the dune morphology. The vegetation plays an important role in capturing sand grains. The development of coastal dune is, therefore, related to the complex set of processes of beach/dune interaction.

Studies on sediment budget and dune/beach interaction are quite abundant (Psuty 1988; Pye and Lancaster 1993; Arens 1994; Davidson-Arnott and Law 1996). These studies have attempted to measure and predict sediment transport from the beach to the dune. Few studies have, however, been done on aeolian processes and the dynamic sediment budget of foredunes in Korea (Seo 2001).

The number of sand dunes on the Korean coasts is 133, of which 19 (14 % of total) sand dunes are only under good condition (Ministry of Environment 2001). Recently, coastal areas of Korea have been the center of large-scale development projects. Industrial, residential, and recreational

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developments are undergoing on the coastal zone. As a result, many coastal dunes have been destroyed or poorly preserved. The coastal dunes are populated by plants and animals and are important for ecosystems between land and sea. Recently in Korea, interest in restoration of coastal dune has been increasing. Successful restoration of coastal dunes requires knowledge about natural processes of foredune development.

The purpose of this study was to measure the seasonal variations of dune/beach morphology and determine the changes in sediment budgets in a beach-dune system over a period of year. The study was carried out over the period 1999-2000 at six sites in a foredune at Seungbong Island, Korea.

2. Study area

Seungbong Island is located 60 km west of Incheon. The island has an area of about 5.77 km^2. The seacoast of the island is composed of small-scale coastal precipices that are shaped by waves and winds. Iilae beach, which is located on the southwestern shore of the island, has a length of 700 m. Sediments in the beach are derived from offshore. A foredune with a length of over 300 m has

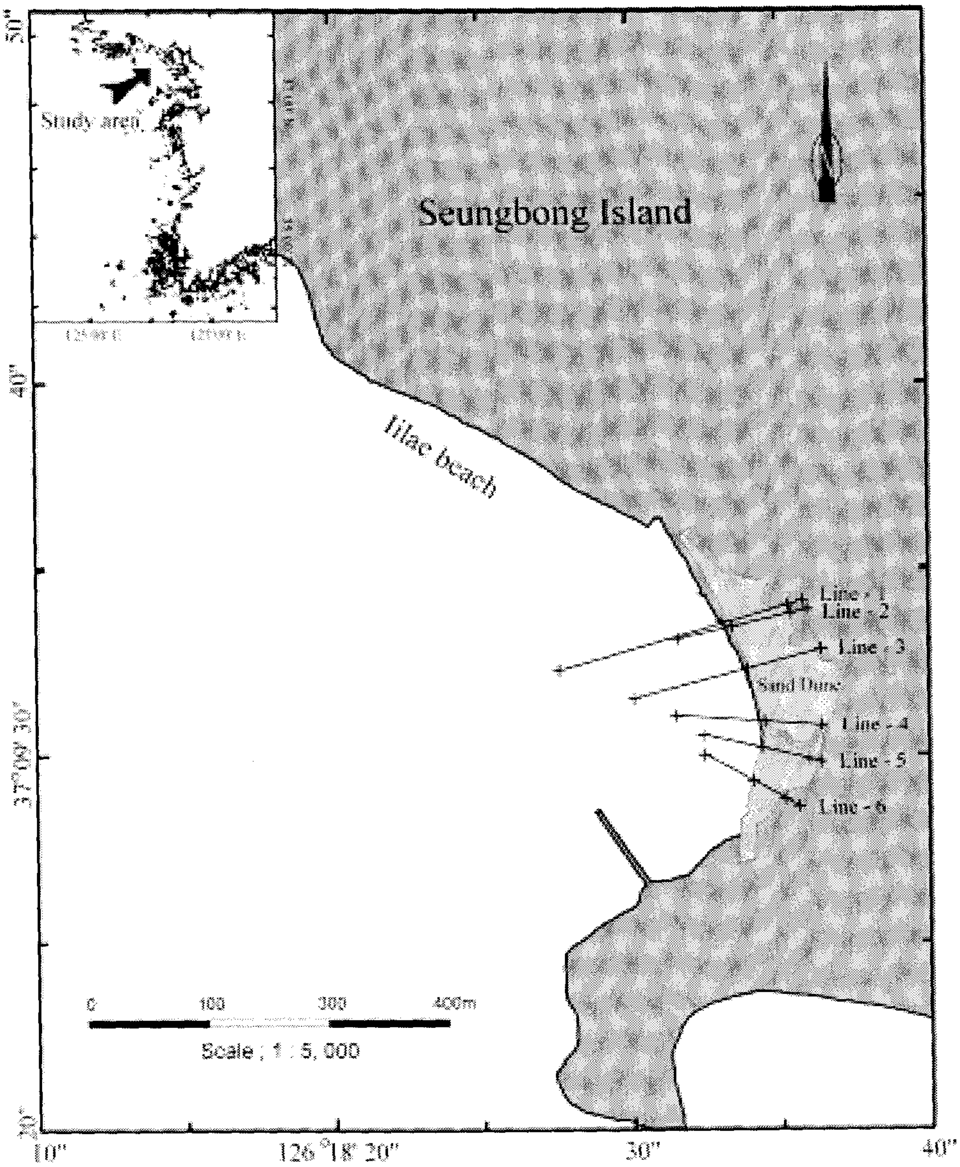

Fig. 1. Location map of the coastal foredune at Seungbong Island showing transect lines.

developed in the southern part of the Iilae beach (Fig. 1). The height of the foredune ridge ranges from 10 to 15 m from the mean sea level. Foredune ridge is colonized by the black pines of over 30-year old. The foredune is vegetated with *Carex kobomugi*, *Rosa rugosa*, *Lathyrus japonica*, *Calystegia soldanella*, *Vitex rotundifolia*, and *Messerschmidia sibirica*, etc.

Meteorological data used in this study were acquired from a weather station in Incheon (Korea Meteorological Administration 1999, 2000). The prevailing and dominant winds in the study area were from the west and northwest from June 1999 to May 2000 (Fig. 2). The strong winds were more frequent in the winter and spring than in the summer and fall. Wind speed was usually high in winter season.

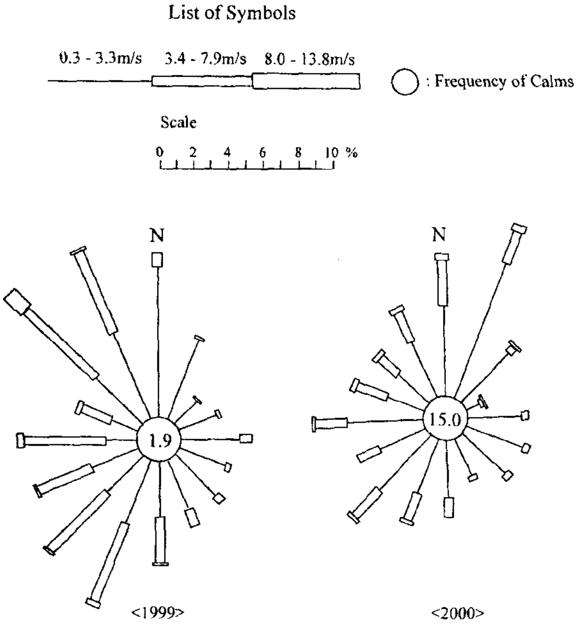

Fig. 2. Annual surface windroses in Incheon in 1999 and 2000 (Korea Meteorological Administration 1999, 2000).

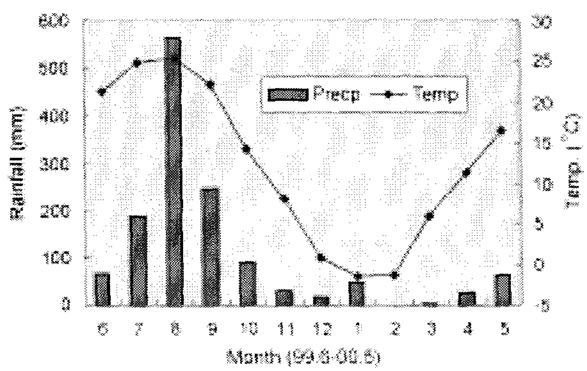

Fig. 3. Meteorological data for Incheon (1999. 6-2000. 5) (Korea Meteorological Administration 1999, 2000).

Annual mean temperature in the study area was 12.4 °C, with maximum mean monthly temperature of 25.4 °C in August and minimum mean monthly temperature of −1.5 °C in January (Fig. 3). In the winter season, daily temperature frequently dropped below 0 °C, freezing dune surface. No movement could be occurred under this condition. Annual amount of precipitation was 1,351 mm. Most of the annual precipitation (79 %) was concentrated in the rainy season, from late June to September (Fig. 3).

3. Methodology

Geomorphic changes due to sediment deposition/erosion within the foredune and beach were measured along six lines using a leveling instrument (Fig. 1). The six lines were established in June 1999. Their locations were determined based on the foredune slope. Each line in the foredune was covered by dense vegetation. The elevation along each line was measured four times during 12 month period (June and November in 1999, and February and June in 2000). Seasonal volumetric variations of the foredune and beach were calculated using the changes in elevation at 6 transects with a computer program Surfer 7 by Golden Software, Inc.

Surface samples were taken from 41 locations along the lines 1, 3, and 5. The sand and mud fractions were separated by wet sieving through a 4 ϕ stainless-steel sieve after removing organic materials and carbonates with 10 % H_2O_2 and 0.1 N HCl. Grain-size analyses were performed using standard sieving (Folk 1980) and a Sedigraph 5100 for the sand and mud fractions, respectively. Inclusive graphic method (Folk and Ward 1957) was used to determine sediment type, mean grain size and sorting.

4. Results

The lines 1 and 2, located on the northern part of the study area, had foredune slopes of approximately 14° and 15.3°, respectively. There was no break between dune and beach profiles. The vegetation was dominated by *Carex kobomugi* with scattered patches of *Calystegia soldanella* and *Messerschmidia sibirica*. These species are frequently observed in a dynamic dune environment.

Fig. 4 shows the cumulative elevation changes in the

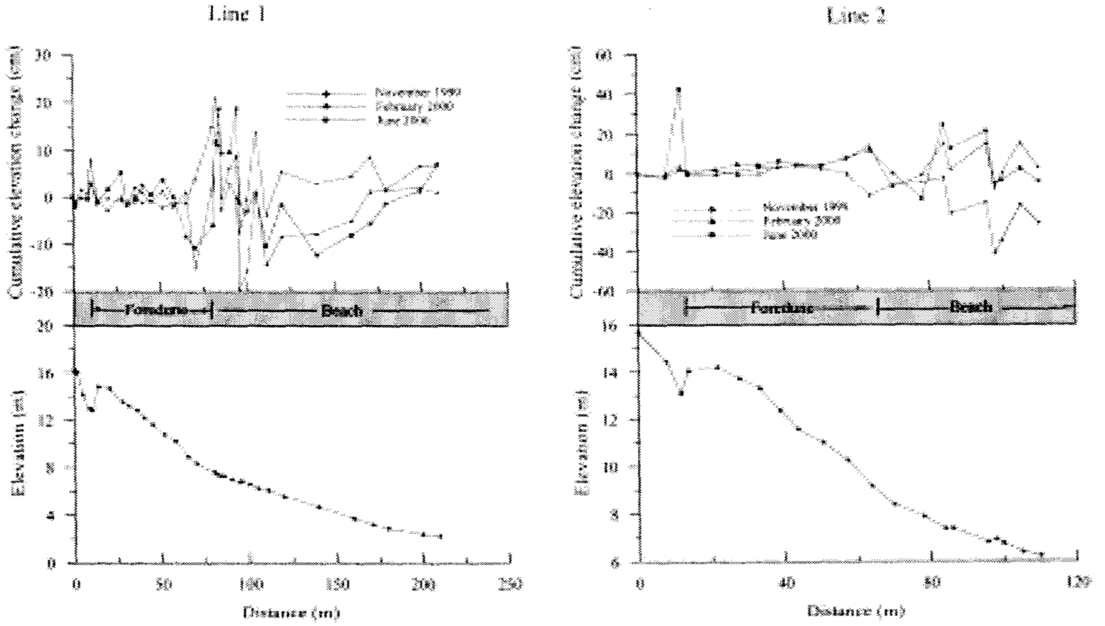

Fig. 4. Cumulative sediment deposition at lines 1 and 2. Profiles along these lines were surveyed in June 1999 and cumulative elevation changes were measured from June 1999 to June 2000.

foredune and beach along the lines 1 and 2 during the study period of June 1999 to June 2000. The foredune in the line 1 showed deposition on the upper slope and erosion in the middle part (31 to 36 m from reference) and near the dunefoot, whereas the foredune in the line 2 showed deposition on the entire foredune during this period. During the summer and fall, erosion occurred over the foredune in the line 1. In the line 2, however, sand was deposited near the crest and in the middle part, yet the large amount of sand was eroded near the dunefoot. With

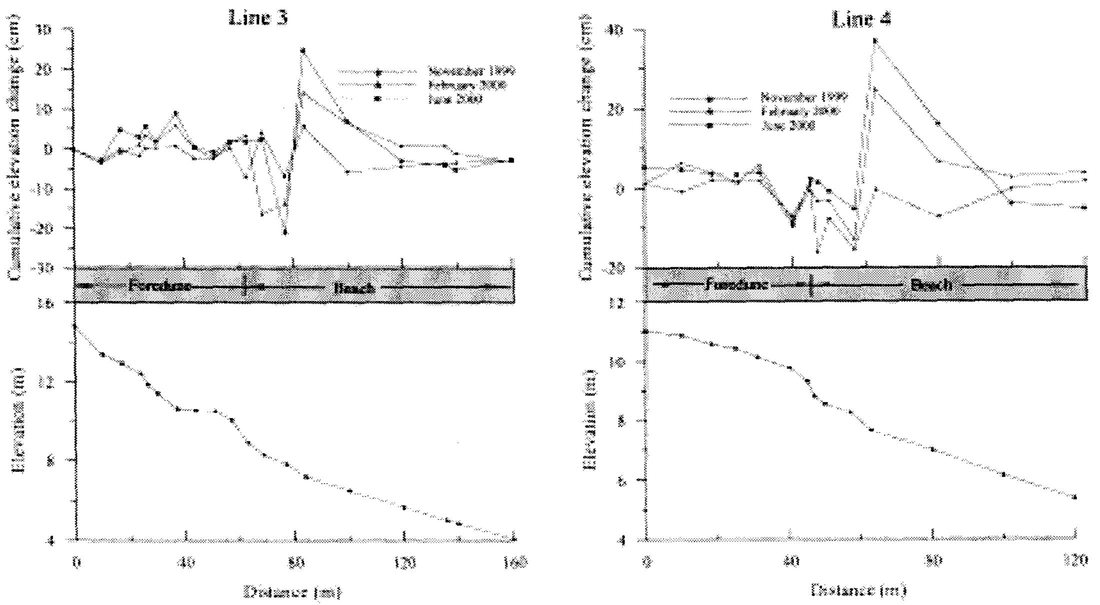

Fig. 5. Cumulative sediment deposition at lines 3 and 4. Profiles along these lines were surveyed in June 1999 and cumulative elevation changes were measured from June 1999 to June 2000.

increasing wind speed in the winter, the sand from the beach moved over the foredune. The deposition/erosion occurred on the foredune in both lines. The main deposition occurred near the dunefoot. During the spring, the sand accumulated over the foredune. On the beach, the sand was eroded in the summer and fall, whereas deposited in the winter, and then, eroded during the spring. In the spring deposition occurred near the foredune and erosion occurred on the seaward slope.

The foredune of lines 3 and 4 which are located on the central part of the study area had relatively lower slopes than other areas, with approximately 13.2° along the line 3 and 13.7° along the line 4. The vegetation was dominated by *Carex kobomugi* with scattered patches of *Vitex rotundifolia* and *Rosa rugosa*.

Generally, the sand of the foredune in lines 3 and 4 was deposited between June 1999 and June 2000 (Fig. 5). During the summer and fall, the sand was severely eroded at the front face of the foredune and dunefoot area, but there were no significant changes in the other area. The sand was eroded on the beach during this period. During the winter and spring, although the sand was partially eroded near the dunefoot, the deposition generally occurred on the entire foredune in lines 3 and 4. The large amount of sand accumulated on the high foredune in the winter and near the dunefoot in the winter and spring. The accumulated sand on the high foredune moved further landward from the winter to the spring because of relatively gentle slope. Because the line 4 was close to a disturbed area, however, those values should be carefully interpreted. On the beach, the sand accumulated on the seaward slope in the winter and mainly accumulated on the front zone of the foredune in the spring. The beach sand moved toward foredune from winter to spring.

The lines 5 and 6, located on the southern part of the study area, were partially protected by a breakwater. The slopes of the line 5 were 16° on the dune crest (9.4 to 38.2 m from reference) and 42° on the foredune (38.2 to 50.3 m from reference). The slopes of the line 6 were 25° and 39° for the dune crest (13.7 to 24 m from reference) and foredune (24 to 38 m from reference), respectively. This area was densely vegetated with *Rosa rugosa* and scattered patches of *Carex kobomugi* and *Elymus mollis*.

The cumulative elevation changes showed that the sand was accumulated on the dune crest and foredune in the line 5. Whereas the dune crest was eroded and the foredune was deposited in the line 6 during the period of June 1999 to June 2000 (Fig. 6). During the summer and fall, erosion occurred on the dune crest, yet deposition occurred on the foredune in the line 5. In the line 6, the sand was deposited on the dune crest and foredune. In the winter, the large amount of sand was deposited over the foredune, but erosion occurred on the dune crest. The sand on the beach was continuously transported toward

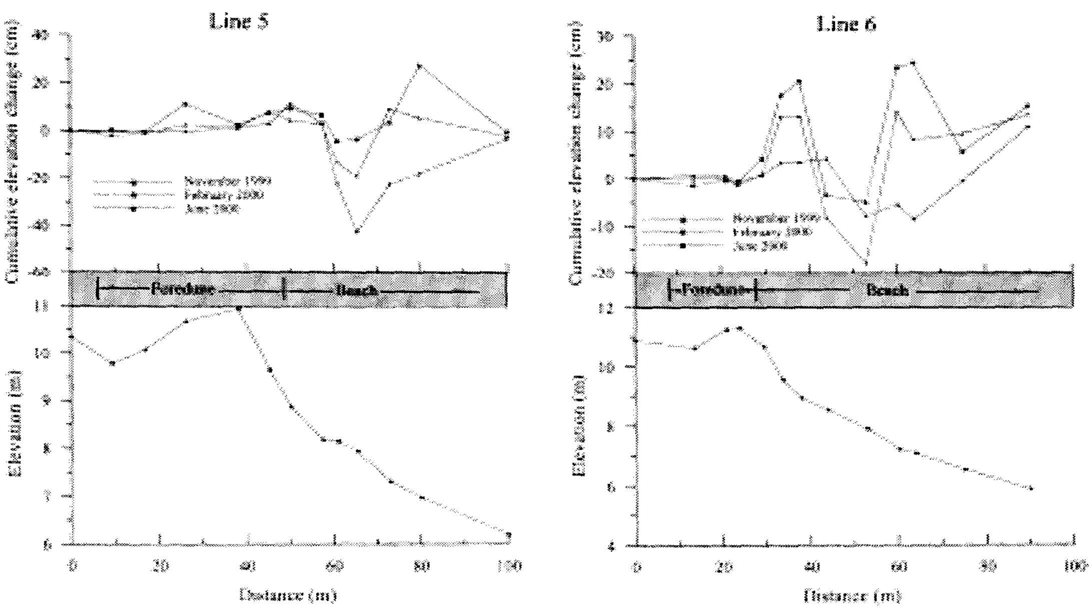

Fig. 6. Cumulative sediment deposition at lines 5 and 6. Profiles along these lines were surveyed in June 1999 and cumulative elevation changes were measured from June 1999 to June 2000.

Table 1. Volumes(m^3) of foredune and beach from the line 1 to 6 from June 1999 to June 2000.

	June 1999	November 1999	February 2000	June 2000
Foredune	130,041	129,912	130,302	130,525
Beach	111,174	110,747	111,660	111,519

the foredune: the dune crest and foredune in lines 5 and 6 were continuously accumulated in the spring. On the beach, the sand was eroded during summer and fall. The sand accumulated on the seaward slope in the winter and moved toward the front zone of foredune in the spring.

Generally, the sediments on the foredune and beach were composed of well-sorted sand with a mean grain size of approximately 2.0 ϕ. The sand on foredune in the winter was slightly coarser than that in other season because coarse sands on the beach were transported to the foredune in the winter.

The changes in elevation at all lines were converted to seasonal volumetric variations between June 1999 and June 2000 (Table 1). Total sediment accumulation over the study period was 484 m^3 for the foredune and 345 m^3 for the beach. The volume of the foredune increased in the winter and spring and decreased in the summer and fall. On the beach, the volume increased in the winter and decreased in the spring, summer and fall.

5. Discussion and conclusion

Sand accumulation in the foredune mostly occurred during the period of November 1999 to June 2000. Sand transport in the study area was largely affected by seasonal wind regime. Prevailing winds are northwesterly in winter season and south or southeasterly in summer season. Much sand was deposited on and/or near the dunefoot in winter. This sand was transported to the foredune from the beach with increasing wind speed in the winter and spring.

Wind speed that can move sand from the beach and dune surface was calculated from Bagnolds equation (Bagnold 1941). Threshold shear velocity calculated from Bagnolds equation was approximately 6 m/s. Wind speed over 6 m/s that is the effective wind speed for moving sands concentrated in the study area between December and early April.

The largest amount of sand was deposited on the dune slope in lines 5 and 6 where there was dense vegetation of *Rosa rugosa*. The vegetation on south foredune was denser than that of other areas. The dense vegetation in this area would, therefore, capture large amount of moving sand because sediment transport rate within the foredune was likely to decrease with the vegetation density. Hesp (1983) and Sarre (1989) observed exponential decrease in transport rates as vegetation density increased.

The longshore current could be another factor for large amount of sand supply in south foredune. Generally, the direction of wave approach was oblique because of the effects of wave refraction in shallow waters (Pethick 1984). Longshore current in the study area might flow from north to south, transporting sediment to the southern part of the study area. Moreover, the southern part was also protected from direct wave attack by the breakwater on the southern tip. As a result of all these factors, a large amount of sand could be accumulated on the southern beach.

Because coastal dunes were very dynamic, the spatial behavioral pattern of sand transport was different from site to site within the same region. Complex deposition and erosion patterns appeared in the northern and central part of the study area, whereas relatively continuous deposition process occurred in the southern part. Variations in sediment deposition in the study area seem to be controlled by the wind regime, vegetation and longshore current pattern. Because the study area has been little affected by human activity, the processes of foredune development described herein provide a baseline for future foredune restoration that will be necessary as the region is developed.

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