RECLAMATION PLANNING FOR ABANDONED MINING SUBSIDENCE LANDS IN EASTERN CHINA — A CASE STUDY[1]

Zhenqi Hu and Hehe Gu[2]

Abstract: China has a long history of coal mining and more than 96% of coal output is taken from underground mines each year. With the excavation of coal from underground, severe subsidence often results, which produces many subsidence lands. Since the Chinese government enacted a reclamation stipulation in 1989, many abandoned mining subsidence lands were produced before 1989. Therefore, reclamation of abandoned subsidence lands has become the focus of research activities in our country. This paper explores the principle and methods of reclamation planning for abandoned mining subsidence lands and presents a case study in eastern China. A 373 ha of abandoned mining subsidence land in Anhui province was selected as an experiment site. Since China is a developing country and land shortage is severe in this area, the high economic benefits from the reclaimed land was the final reclamation goal. Based on the topography of subsidence lands — some parts of the abandoned lands were wetland or lake-like troughs, restoring farmlands and fishponds were chosen as post-reclamation land uses. The elevation of reclaimed lands was the key for restoring farmland successfully because of the high underground water level in this area, and the optimum fishpond size and side-slope design were the keys to reach high reclamation income. The HDP (Hydraulic Dredge Pump) reclamation technique was used for restoring farmland and creating fishpond. A farming and aquaculture plan for high economic benefits was also designed. This project will make farmers, who own the lands, richer through reclamation.

Additional Key Words: reclamation principle, farmland reclamation, hydraulic dredge pump, reclamation benefits.

Introduction

In China, most of the coal is taken from underground mines, accounting for 96% of the coal output. Underground coal mining has caused a large amount of lands to subside, which has led to farmland losses and caused severe conflicts between farming and mining. According to statistics, the lands subsiding from coal mining are more than 13,300 hectares each year, of which half is located in the plain area, which is all prime farmlands (Sun and Li 1990). It is well known that China has a very large population and the cultivatable land shortage is very serious. The mean cultivatable and permanent farmland per person in China only equals about one-fourth of the average value in the world. This situation makes the reclamation of subsidence lands become an urgent task for our country. The purpose of reclamation is to create higher land productivity so that the Chinese people can obtain foods from the reclaimed lands and having higher incomes.

Reclamation planning is an important step, which effects post-reclamation land use and subsequently effects the amount of investment and reclamation effectiveness. Since mining subsidence in China is more serious than in the U.S., reclamation planning for subsidence land in China might be more difficult than in the U.S. This paper explores the principle and methods of reclamation planning for abandoned mining subsidence lands and presents a case study in eastern China.

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Experiment Site Description

The experiment site was located at the North-Anhui Coal Company, Liuqiao mine near Shuixi, in Huaibei City, Anhui Province, eastern China. The subsidence land due to the underground mining by Liuqiao mine belonged to Zhoukou village. The population was about 2742 with about 400 hectares of land, of which most was prime farmland. This area was in the range of the Huaibei National Marketable Grain Base.

Liuqiao mine is an underground coal mine, which produces about 1.2 million tons of coal per year by use of longwall mining excavation system. The thickness of coal seam is 2m - 4m. Most of it is 2m. The slope of the coal seam is about 30 degrees. The mining depth is 176m - 341m. Due to the high underground water level and thick alluvium in this area, the subsidence factor is almost equal to 1. Thus the maximum subsidence depth could reach 1.7m - 3.4m and some subsidence areas accumulate water. Thus, about 373 hectares of land was destroyed by mining subsidence in Zhoukou village, accounting for 93.25% of total village land. Of the subsidence lands, about 91.8 ha of prime farmland lost its productivity permanently and 61.1 ha could only be used seasonally. Farmers' houses were destroyed by mining subsidence, which lead to the moving of their residence. Roads and banks of rivers and ditches were also damaged due to mining subsidence. There were about 147.4 ha of prone lands in the subsidence area, which were all low productivity. Most farmers became unemployed following mining. Therefore, the reclamation of the abandoned subsidence lands became an urgent task. The information on the subsidence lands in this village is illustrated in and figure 1. The figure 2 is the geographical map of Zhoukou subsidence land, Anhui, China.

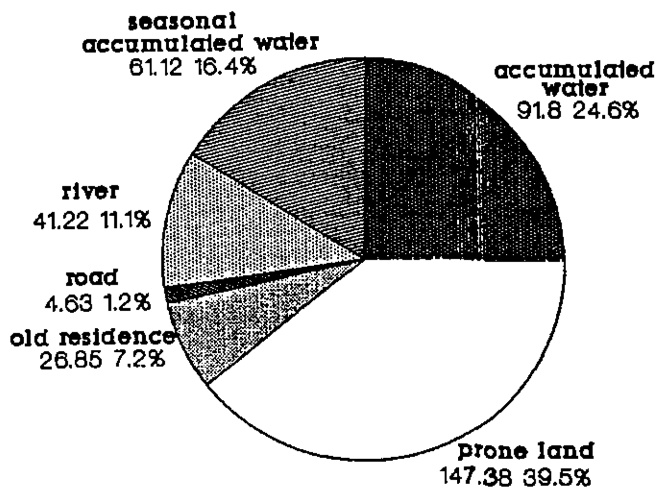

Figure 1. The distribution (ha) of Zhoukou subsidence lands, Anhui, China.

The Principle of Reclamation Planing

In China, the general principle of reclamation planning for subsidence areas is (1) following the overall local land use plan, a rational post-subsidence land use should be designed based on the status of the subsidence land and its stability; and (2) an optimum reclamation treatment and its technical process should be determined so that the reclamation effectiveness could be maximized at a minimum of cost (Hu et al. 1994a). According to the local status of Zhoukou subsidence lands, the following principles were determined:

1. Since most of Zhoukou subsidence land was prime farmland, the reclamation target as much as possible should be restoring cultivatable land for producing marketable grain.
2. Economic benefits of reclamation should be most important while considering environmental and social benefits so that farmers living in the subsidence area could have jobs and could become richer through reclamation.
3. Making an overall plan and determining suitable land-use types based on local conditions. The land suitable to cultivation should be restored to cultivatable land and the land suitable to aquaculture (or livestock farming) should be designed as an aquatic farm (or livestock farm).

4. Make use of all the land and determine rational distribution of land-use types.

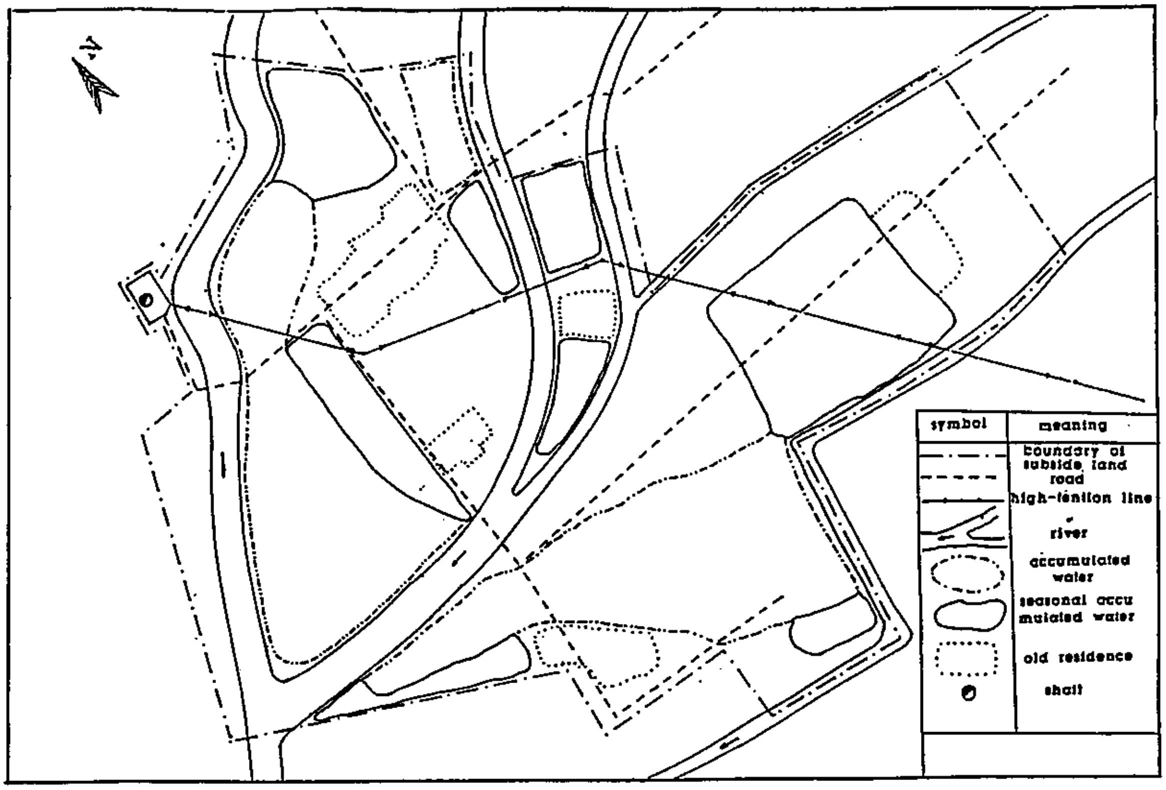

Figure 2. The geographical map of Zhoukou subsidence lands, Anhui, China.

The procedures for reclamation planning were: (1) Collection and analysis of all data related to local topography, geology, hydrology, soil, climate, land-use, population, needs of people and mining; (2) Analysis of reclamability of the subside land, which includes the analysis of soil, water and environmental conditions and the analysis of stability of subsidence lands; (3) Design a land-use plan for the subsidence lands, which mainly includes the selection of land-use types and determination of their distribution; (4) Design of the reclamation engineering, which includes earthwork and biological reclamation engineering; (5) Investment analysis and income estimation.

Reclamation Plan

Land-use Plan for Reclaiming Zhoukou Subsidence Lands

It is well known that additional soils are needed for restoring subsidence lands to their original contour. Since there is a shortage of soil materials, we have to strip some "deep areas" of the subsidence land to obtain soils as filling materials (Hu et al. 1994b). Thus, constructing fish ponds for aquaculture may produce extra soils, which might be used for raising some "shallow areas" of subsidence lands to a desired elevation. Restored cultivable land could produce marketable grain and the constructed fish ponds could provide fresh aquatic products. Therefore, this sort of reclamation could produce higher economic benefits. The detailed reclamation plan was (see Fig.3 and Fig.4):

1. Restoring about 227.82 hectares of cultivable land for farming and livestock. The needed soils for raising the subsidence lands to a desired elevation was about 989,000 m^3. Of the total cultivable lands, 223.91 ha of land are for farming and 3.91 ha are for livestock farming. Based on the needs of the local people and local conditions, livestock farms with chicken, pigs, ducks and cattle were designed. The

distribution of the livestock farming land was: chicken 1.05 ha, pig 0.99 ha, duck 0.75 ha and cattle 1.12 ha.

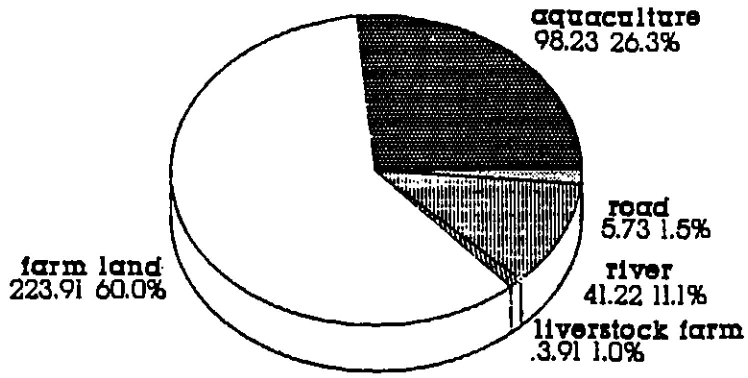

Figure 3. The distribution (ha) of reclaimed Zhoukou subsidence lands, Anhui, China.

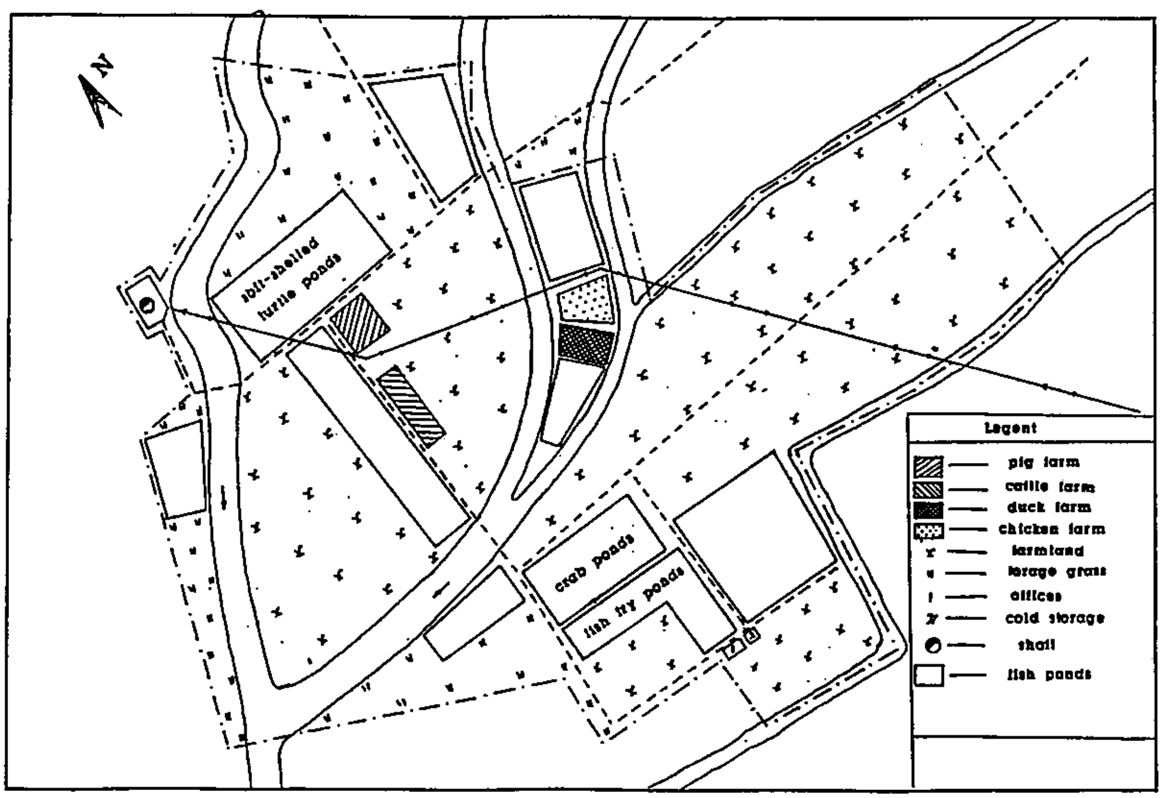

Figure 4. The map of reclamation plan at Zhoukou, Anhui, China.

2. Digging "deep areas" of the subsidence lands for constructing fish ponds for aquaculture so that the excavated soils could be used as filling materials for raising the elevation of "shallow areas". The designed aquatic farm land was 98.23 ha. The total amount of excavated soils was 1,209,000 m^3, which was enough to restore subsidence lands to cultivable lands with a desired elevation. To obtain high economic benefits, some odd species of aquatic animals such as soft-shelled turtle and crab were selected. The distribution of aquatic farm land was: fish ponds 73.15 ha, fish fry ponds 6.44 ha, crab ponds 7.64 ha and soft-shelled turtle ponds 10.99 ha.

3. Rebuilding roads and banks of rivers and ditches.

Reclamation Method

The main tasks of reclaiming the Zhoukou subsidence land were to construct fish ponds and restore some cultivatable lands. The hydraulic dredge pump (HDP) reclamation method could complete the two tasks at the same time (Hu et al. 1994b). Thus, HDP was chosen for the earthwork engineering.

The HDP is a set of machines with a high-pressure pump, two hydraulic giants (water syringes), a slurry pump and some steel and plastic pipes. The HDP machine simulates natural water erosion and turns the mechanical and electrical power into hydraulic power for digging, transporting, and filling of soils. Usually, earthwork requires five procedures such as excavating, loading, transporting, unloading and leveling of soils, and particular machines such as excavation machines, trucks, bulldozers, etc. are needed in each procedure. But, the HDP method provides four procedures (excavating, loading, transporting, unloading) at one time. Thus, the method has many advantages such as: the equipment is simple, the cost is low, the operation efficiency is high, and the operation is convenient and not affected by weather.

The procedures for HDP operation used in the reclamation of our subsidence lands can be summarized as follows:

1. Produce high-pressure and high-speed water by a high pressure pump. Usually, the water speed is 50 m^3/h.
2. Excavate soils by use of hydraulic giants (water syringes) with the high-pressure and high speed water, which makes the soil become a slurry.
3. Transport the slurry to the "shallow areas".
4. Fill and settle. The slurry can be filled in the designed "shallow areas" by moving the transportation pipes, then letting the slurry settle down naturally. A drainage system is needed for quickly settling down the slurry. Generally, the filled lands need more than 5 months for settling after the completion of the filling work.
5. Level the reclaimed land by hand or dozers.

Design of Biological Reclamation and Other Necessary Treatments

The HDP method was used for earthwork in the reclamation engineering for Zhoukou subsidence lands. Biological engineering and other necessary treatments planned were:

1. Farm plan: The total farming land was 223.91 ha. Based on the soil conditions and the needs of local people, 140.59 ha of land was planned for producing marketable grain with the rest designed for tobacco, strawberry, grape, forage grasses and medicinal herbs. The land distribution was 14.93 ha tobacco, 13.33 ha strawberry, 10.78 ha grape, 33.96 ha forage grasses and 10.32 ha medicinal herbs. Since reclaimed soils from HDP was poor, amelioration treatments are needed. According to reports from other reclamation areas, the pioneer crops to be planted in soil reclaimed by HDP are pulse family crops. Grass family crops should be planted after amelioration of the soils.

2. Aquaculture plan: The aquatic farm is another important type of land use in the reclamation plan. It has been proven that the economic income from 1 ha of fish pond is equal to or greater than that of 150 ha of farmland. Optimum fishpond size and side-slope design are keys to reach high reclamation income. The standard fish pond is about 0.67 ha with 120m length and 60m width. The side-slope is 1:2.5 or 1:3 and the water depth is 2.5m -3.0m. For soft-shelled turtle culture, the water depth should be about 2.0m.

3. Livestock farm plan: The livestock farm will include a chicken farm with 20,000 chickens, duck farm with 10,000 ducks, pig farm with 1,000 pigs and a cattle farm with 200 cattle.

4. Other treatments for forming a complete system are:
   (1) A feed-processing plant with the production of 10,000 tons per year could be established for aquatic culture and livestock farming.
   (2) A strawberry-processing plant with the production of 30 tons per year could be established.
   (3) A cold storage should be built for storing aquatic products, eggs, etc.
   (4) Two methane-generating pits with 100 m^3 volume could be built for making use of livestock excrement. Based on the principles of ecological engineering, recycling of livestock excrement could

be designed as in figure 5.

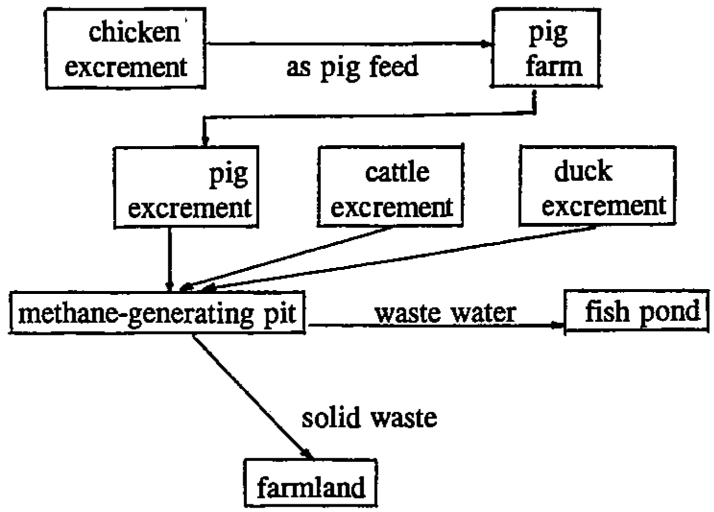

Figure 5. The recycling of livestock excrement.

Analysis of Investment and Income Estimation

To complete the reclamation plan, a total 24,294 thousand yuan would need to be invested. The details of the reclamation investment are listed in table 1.

Table 1. The plan of reclamation investment (unit: thousand yuan).

Project	Basic engineering	Aquaculture	Livestock farming	Farming	Other	Sum
invest	9900	649	5760	3233	4752	24294
percent	40.8	2.7	23.6	13.3	19.6	100

Approximately 5.8 million yuan in economic benefits should be obtained each year. Thus the payoff period of the investment would be 4 to 5 years. The detail estimation is that:

(1) Farming: The 140.59 ha of land for marketable grain would return 211 thousand yuan. The remaining farming land for tobacco, strawberry, grape, forage grasses and medicinal herbs would return 720.4 thousand yuan. The total economic benefits from farming land could reach 931.4 thousand yuan.

(2) Aquaculture: The 73.15 ha of fish ponds might produce 1,646 thousand yuan while odd aquatic products produce 1,474.6 thousand yuan. The total economic benefit from aquaculture might reach 3,120.6 thousand yuan.

(3) Livestock farming and processing plants: About 600 thousand yuan in economic return could be obtained from the overall livestock farm and about 1,150 thousand yuan could be returned from the feed-processing plant, strawberry-processing plant and others.

Conclusions

Since the reclamation purpose of subsidence land is different between China and the United States, the reclamation plan is subsequently different. This paper introduced principles and methods of reclamation planning based on a case study in Eastern China. If this reclamation plan were conducted, high economic benefits, high social and environmental benefits such as restoring farmland, controlling pollution, providing jobs could be obtained. Since reclamation is a new field in China, the need for international cooperation is imperative to obtain high reclamation effectiveness.

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REVEGETATION EXPERIMENTATION ON AN ABANDONED COPPER MINE IN CALIFORNIA [1]

by

Karen Wiese [2], Vic Claassen [3], and Gail Newton [2]

Abstract. Disposal of sulfide-rich mine tailings in combination with rain water and air have resulted in Acid Rock Drainage (ARD) degrading surface and ground water at the abandoned Spenceville Copper Mine in the central California foothills. Lack of a vegetative cover has resulted in eroding slopes and sediment loads contaminating the local drainage of Little Dry Creek. Limiting the movement of reactive waste materials and surface water flow over tailings would greatly reduce contaminates entering the creek. The development of a sustaining, low cost, and low maintenance vegetative cover is an integral part of a comprehensive acid rock drainage abatement strategy for the abandoned mine site because of the ability of the vegetative cover to reduce percolation by evapotranspiration and by reducing surface erosion. In an attempt to reduce the cost of importing topsoil and the environmental degredation that ensues when topsoil is removed, we chose to utilize the substrate onsite for growth media. The research described in this paper describes the first phase in developing reclamation strategies that will produce a self-sustaining vegetative cover able to reduce ARD at the Spenceville Copper Mine.

The tailings and exposed waste materials have little plant available nutrient levels, a low pH, and high heavy metal concentrations. Three categories of barren waste were identified based on geochemical characteristics. Analyses were conducted on the waste material to identify growth limiting factors. To develop a growth media capable of sustaining vegetation, test plots were installed on each type of mine waste and contrasted three different treatments 1) waste lime plus nutrients, 2) biosolids (composted sewer sludge) plus waste lime and nutrients, and 3) nutrients only.

Native and non-native plants were grown in test plots onsite in each of the growth media treatments. Plants in the test plots were monitored for seed germination and survival, plant growth and vigor.

Additional Key Words: Acid Rock Drainage, Abandoned Mine, Biosolids, Revegetation

Introduction

The Spenceville Copper Mine had been worked almost continuously between the 1860s and 1918. In the years that the site was in operation, copper, paint, and sulfuric acid were produced. The depth of the mine proceeded to between 100 and 150 feet with the original tunnel broadened into an open pit excavation. Extracted ore was roasted and copper extracted by leaching. Waste dumps of the original underground mine were reworked by water leaching and precipitation on scrap iron.

The site currently consists of leached ore, roasted ore, low grade ore or waste rock dumps, and the pond which fills the mine pit. The large open pit is surrounded by several acres of tailings which lie in terraces up-slope of the pit. Mining has caused the exposure of copper-rich sulfates and iron pyrite to oxygen and water. The chemical reactions and leaching of the tailings and pyrite rich wall rock in the mine pit has resulted in the generation of acid rock drainage (ARD) in the form of sulfuric acid and the

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