



CHANGES OF A ROUTE AND AN UPSTREAM WELL FOR AN INVERTED SIPHON OF TATSUMI CANAL IN THE CITY OF KANAZAWA

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ABSTRACT

Tatsumi Canal is famous for its long tunnel and an inverted siphon between Kodatsuno terrace and Kanazawa castle with high water head. However, due to lack of documents written at the time of construction details of neither the chief engineer nor construction design have not been specified. This paper discusses a unique feature applied to tunneling to speed up the construction. The technology is supposed to be transferred from mining which prospered in Kaga feudal domain. The paper clarifies large-scale restoration of the canal after a big earthquake in 1799 through a drawing which is donated to Ishikawa Prefecture in 2016 by a descendant of the director of the restoration and became available publicly. The final destination of the canal is Kanazawa castle and for security reason an underground water pipe, that is, an inverted siphon is required to overcome a moat of the castle. Historical changes of a location of an inlet of the inverted siphon were also clarified by extensive study of traditional drawings.

Keywords: Inverted siphon, Tatsumi Canal, Edo period

1. INTRODUCTION

Tatsumi canal was constructed in 1632 by the order of Maeda Toshitsune who is the third lord of Kaga Clan during Edo period. The most important objective of the canal is to obtain water resources for extinguishing fires which frequently destroyed large areas of a castle town and a part of the castle. There are many remained questions on the canal because there is no exists recorded material written at the time of the construction. However, we can trace historical transitions of the canal since early eighteenth century through books and drawings. Although the canal experienced several changes caused by river bed degradation and a big earthquake in 1799, the most part of the canal retained its original form and the canal was designated as a national historic site in 2010.

A total length of the canal is approximately 11 km between the intake at Kamitatsumi village from Saigawa River and Kanazawa castle. Most upper part of the canal starting from the intake has been constructed by unlined tunnel whose length amounts to approximately 3.3 km. The canal conveys water to Kanazawa castle through an inverted siphon crossing a wide moat of the castle. Maximum water head of the inverted siphon is estimated about 16 m which is quite large value in Edo period in Japan. During Edo period the canal was owned and totally operated by the Kaga feudal government under Maeda Clan who has been named the ruler of Kaga domain by Tokugawa Shogunate. Tatsumi Canal supplied water to wide fronts, for example, firefighting, moats of the castle, gardens and for a better environment of the castle, Kenrokuen Garden, irrigation, and water power for a powder plant of the Kaga feudal government.

By Meiji Restoration political power moved from Tokugawa Shogunate to a new government under Emperor in 1868. Japan experienced turmoil due to the transition of political power in several years. After such turmoil, a new managing body for Tatsumi Canal was gradually organized under the leadership of the prefectural government of Ishikawa. A major function of Tatsumi Canal changed to irrigation and a union of farmers was organized for the management of the canal. The inverted siphon stopped supplying water to Kanazawa Castle in Meiji period because the Kaga feudal government in the castle was disassembled.

2. CHARACTERISTICS OF TATSUMI CANAL PROJECT

2.1 Topographical features of Tatsumi Canal

City of Kanazawa is located in the center of Ishikawa Prefecture as shown in Figure 1. The city center is divided into three by Saigawa River and Asanogawa River, and is surrounded by Utatsuyama Hills, Kodatsuno terrace and Teramachi terrace, which are listed from the north. The Kanazawa castle is located on the edge of the Kodatsuno terrace as shown in Figure 2.

The canal, approximately 11km in length, starts from the Higashi-iwa intake on the left bank of the upper Saigawa River. The canal flows through in a tunnel of approximately 3.3km long, connects to an open channel part on a west slope of Kodatsuno terrace, and finally reaches Kenrokuen garden. Average gradient from 'Kiji' (the first intake) to the Kenrokuen Garden is approximately 4‰, but it is approximately 1‰ to the Nishikimachi town on Kodatsuno terrace in the upper part of Tatsumi Canal which is mainly composed by tunnels.

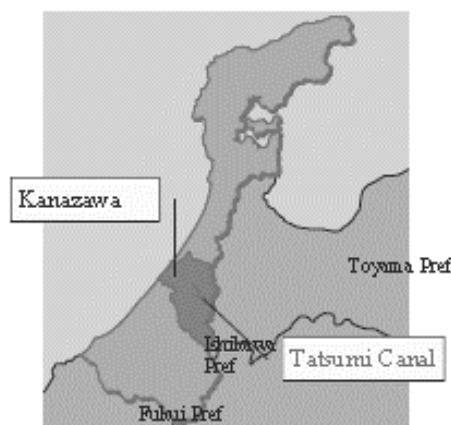


Figure 1. Location map of Tatsumi Canal

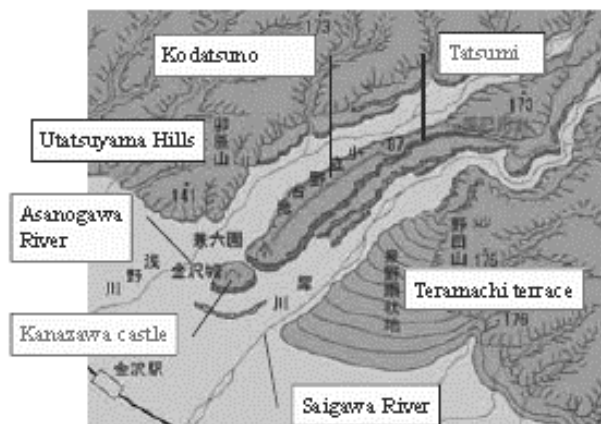


Figure 2. Geography around Kanazawa castle

2.2 Unique feature in tunneling technique

Two advanced technologies at the beginning of the 17th century, a long tunnel and an inverted siphon with high pressure, are used in the project. It is notable that the construction took only 9 months to complete the canal including the inverted siphon which conveyed from Kenrokuen garden to Kanazawa castle.

There are several canals in Japan where tunnels were dug in the 17th century, but in Tatsumi canal, a unique method of construction was adopted. As shown in Figures 3 and 4, there were many adits toward the terraced cliff at the wall about 20 to 30 m apart in the tunnel. Such an adit was called "a window" and was used for ventilation, day lighting and to carry out the earth and sand generated by digging the tunnel. It helped to shorten a construction period by subdivided sections which made simultaneous construction possible in many sections.

In addition, since the height of the entrance of adit almost accords with the riverbed height of Saigawa in the late Quaternary Pleistocene, it is thought that it was possible to construct the canal at low-gradient by setting the riverbed height of the canal in a standard in the riverbed of the time when Kodatsuno terrace has begun to form it (Aoki, 1983).

In the canal which adopted the same method of construction at the same period, there is Iwazeki Canal in Akita feudal domain (current Akita prefecture). It was reported that this canal which completed in 1631 was built using drainage holes technology in mines and the tunnel of this canal was similar in shape and linearity to the Tatsumi Canal (Aoki, 1989). The Akita feudal government owned domestic eminent silver mines in those days, and it is left for the record that many prospectors from Kaga feudal domain earned their living by working in the silver mine (Yamaguchi, 2008). From the fact that 11 mines were in Kaga feudal domain at that time (Ogawa, 1962), it can be thought that mining technology was applied to Tatsumi Canal tunnel construction method, and a large number of miners working in mines in the Kaga feudal domain were mobilized to dig a tunnel.



Figure 3. Main tunnel (left) and an adit (right)



Figure 4. Illustration of Tatsumi Canal in 1809 ([Bunka-Rokunen-Tatsumi-Yosui-Ezu[1]])

2.3 Restoration from severe damage by earthquake

There are several drawings which wrote the whole of Tatsumi Canal at the period of Kaga feudal domain. The oldest drawings among these were written after the 1799 big earthquake. It can be confirmed that after the earthquake, several sections were replaced with tunnels and Sandan-Ishigaki (the three-tier masonry wall of about 260m in length, Figure 5) was constructed in the Mekuradani valley considered to be the most vulnerable geology (Figure 6). When comparing other drawings written after this, it can be confirmed that the section from the middle part of the tunnel section to the downstream section had been changed from the open channel to a tunnel and the intake had been extended. The current tunnel length from Higashi-iwa intake to Saigawa Purification Plant is approximately 4.8km and Yuno-tani section is approximately 0.3km.



Figure 5. Sandan-Ishigaki

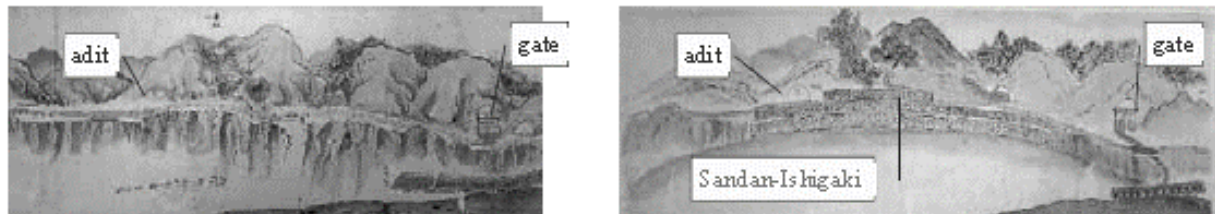


Figure 6. Illustration around Mekuradani valley before (left) and after (right) the 1799 earthquake (Tatsumi-josui-esuji-no-ezu [6])

In this way, as a result of tracing the historical change of the canal, the length of the tunnel before the 1799 big earthquake is approximately 3.3km, and it is thought that the reason why it continued remodeling after the earthquake was to prevent the open channel from being buried by cliff collapse and to get more stable quality of water. As will be described later, demand for water at the terminal of the canal including Kenrokuen Garden increased after the 19th century. In Meiji period, the management of the main constituent of Tatsumi Canal turned into a private sector from the Kaga feudal government. In the end of Meiji Period, an inspection of tunnel part of the canal revealed that a large-scale rehabilitation to prevent the collapse of the deteriorated tunnel was required. Then a maintenance construction was planned and the reinforcement by piling-stones with an arch type was carried out (Figure 7). As a result, most of the tunnels of the upstream part retained its original form while many of the canals constructed in the Edo period has been renovated with lost proof.



Figure 7. Tunnel by piling-stones with an arch type

3. HISTORICAL CHANGE OF ROUTE OF A PRESSURIZED SECTION OF AN INVERTED SIPHON

3.1 Outline of land use change in current Kenrokuen garden area

It is necessary to know the change of land use of current Kenrokuen garden area because an upstream well of the inverted siphon is located in the area. At first in the 17th century, Kenrokuen Garden area was a district of samurai warriors where the chief vassals of the Kaga clan were stationed with subordinates. From the topographic point of view, Kanazawa Castle needed strong defensive base against enemy's attack from the Kodatsuno terrace (southeastern direction). For further defensive purpose, a vast moat exceeding 100m wide was installed in front of Ishibiki Street which runs to southeastern direction.

In 1676, the fifth lord Tsunanori made Renchitei garden in the slant place on the underside of the samurai district, and he gradually relocated the group of samurai warriors to create a vacant lot owned by Kaga clan in 1697. This flat vacant lot above the Renchitei garden is called Chitosedai, and some of the sites were returned to the vassal, but it remained unused for a while. In 1792, the eleventh lord Harunaga constructed Meirindo School of higher education for young samurai in Chitosedai.

In 1822, the twelfth lord Narinaga removed the school and built a magnificent mansion for his retirement life and named it Kenrokuen. At this time, a road which separated the Renchitei garden and the school was abolished, and the integral utilization of these sites started. After Narinaga's passing, the thirteenth lord Nariyasu removed the mansion and changed the whole area to a Japanese style garden. The vast moat for the defense was landfilled when his mother's retirement residence was built in 1863. The placement of current Kenrokuen Garden was almost completely prepared in those days.

In this chapter change of an upstream well location of the inverted siphon of Tatsumi Canal is investigated in four periods based on the change of the land use and construction works in Kenrokuen garden area.

3.2 First Period (year 1632 to 1634)

Mitsubo Kikigaki [2] (In this study old documents and drawings are listed by number in rear part of journal papers and books in modern system) explains that Tatsumi Canal changes to a buried water pipe at the north side of the residence of Okumura family (shown in Figure 8 (Enpokanzawazu [3]). Let us call this location the Point A hereafter in this study and the point are shown by a red circle in Figure 8.

From a comparison between Figure 1 and a current map, the point A is located at a top of the slope of the Kodatsuno terrace (48m above sea level). When the point A is taken as an inlet of the inverted siphon to the castle, it is higher than that of Sannomaru Fortress of the Castle (44.6m above sea level) but lower than Ninomaru Fortress of the Castle (50m above sea level). Therefore, it was up to Sannomaru Fortress to be able to supply water at the time of completion in 1632 [4].

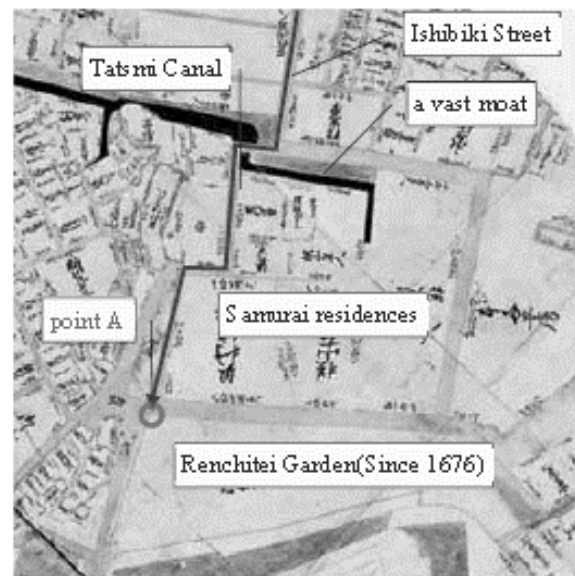


Figure 8. Kenrokuen area in the 17th century (Enpokanzawazu [3])

3.3 Second Period (year 1634 to late 18th century)

In order to supply water to Ninomaru Fortress, it was necessary to move the inlet further upstream and to extend buried water pipes. The final goal of the canal was the main office and the residence which were located in Ninomaru Fortress.

When excavating the bottom of the canal at the time of road construction in 1981, a wooden water pipe was excavated for about 300 meters (Figure 9). As a result of carbon analysis, the pipe was estimated to have been built in the 17th century, and the inlet was thought to be Ishibiki gate which was stated in the historical book "Etsutoga Sansyushi" in the early 19th century. The historical book stated the total distance of the buried pipes from the intake to Renchitei, but the position of the gate was unclear [5].

In recent years, the oldest drawing among which a whole route of depicted Tatsumi Canal was discovered. This drawing [6] makes the gate position clear since the distance and content written on this drawing are totally consistent with the contents of several historical books. When we take a reference point at a step boundary of Kodatsuno terrace, it is clarified that the upstream edge of the wooden water pipe starts from a downstream of identified location of Ishibiki water gate (Figure 10).

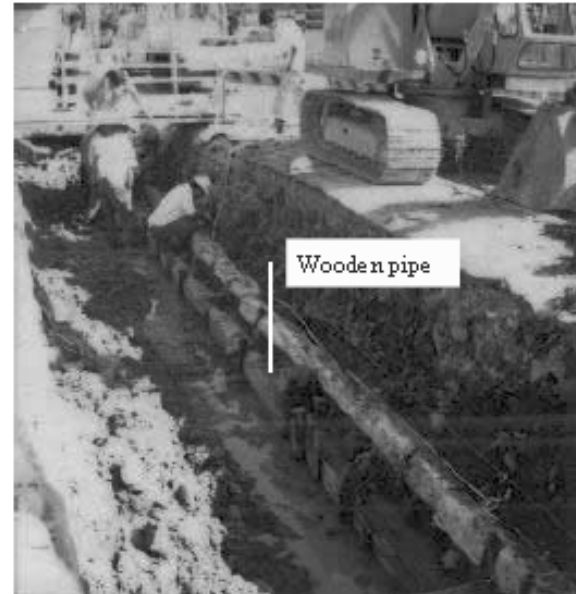


Figure 9. Buried wooden pipes at a construction site (photo by M. Azechi, 1981)

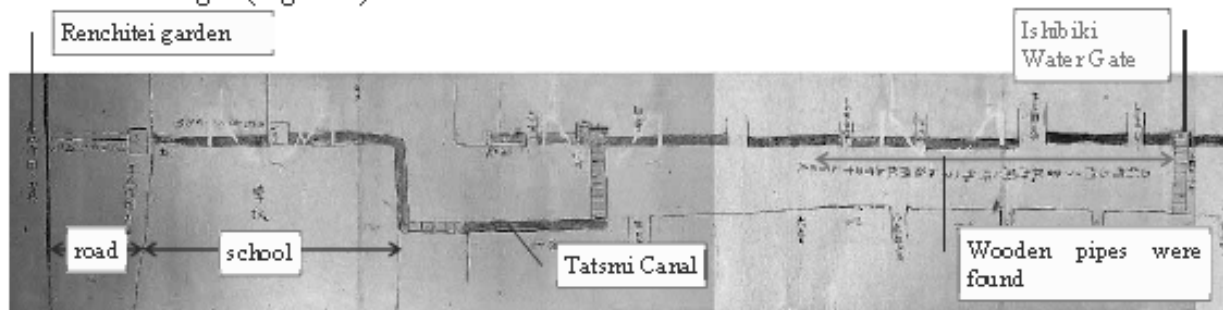


Figure 10. Position of the Ishibiki water gate in Tatsumi Josui Esujino Ezu [6]

A long pressurized wooden pipe was installed in two years until 1634, which is said to be possible to supply water to Ninomaru Fortress since the distance from the gate position (point B) to the point A exceeds 1 km. The maximum water head of the inverted siphon which is generated between the B point (55m above sea level) and the earth paved dike passing a moat (38m above sea level) is estimated about 17m, and it is quite large value in Edo period in Japan.

The wooden water pipe which was excavated the bottom of the canal has a structure similar to that used in the Kanda Aqueduct in Edo (Figure 11), and it can be thought that aqueduct technology at the time was applied to supply water to the castle.

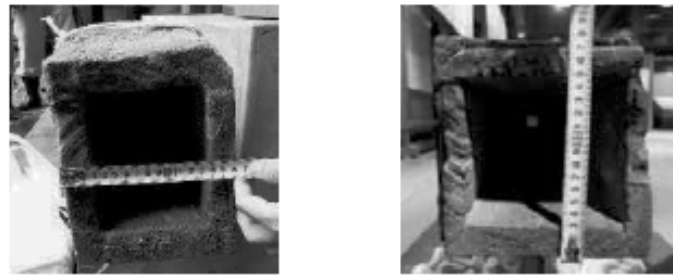


Figure 11. Wooden pipe section in Tatsumi Cana (left) and Kanda Aqueduct (right)

3.4 Third Period (between late 18th century and middle 19th century)

It was difficult to manage this long inverted siphon, and it was necessary to shorten the length as much as possible. Then we estimate when the inlet moved to the position on the downstream side from point B and still possible to supply water to Ninomaru Fortress. In "Kanazawajyo Gotenzu" [7] which is a castle map drawn around 1750s, the inlet is drawn in the Renchitei Garden (Figure 12). In addition, in "Kanazawajyochu Mizunote no hizu" [8] which describes the route of the inverted siphon in the castle in 1807 (Figure 13), the distance from the inlet to the Ishikawamon gate was written.

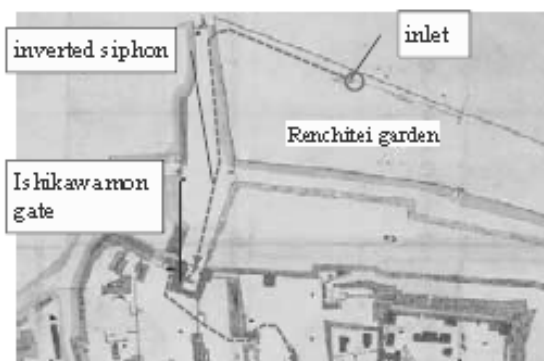


Figure 12. Kanazawajyo Gotenzu [7]

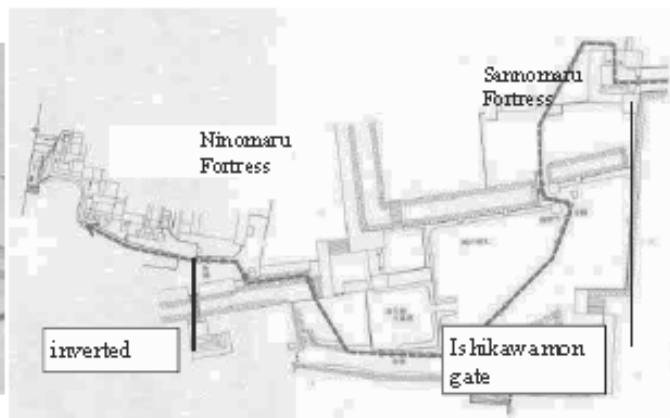


Figure 13. Kanazawajyochu Mizunote no hizu [8]

As a result of estimating the position of the inlet (point C) while comparing these drawings with the current drawing the altitude at point C is 51 to 52 m (Figure 14), and it is confirmed that it is possible to supply water to Ninomaru Fortress.

The reason why the inlet was moved to point C is because it was possible to change the canal's route in the period when it became a vacant lot from the samurai residence, on the other hand, it is recorded that the canal was flowing in the Renchitei garden in 1730 [9], so it can also be thought that it was moved to draw water into the garden.

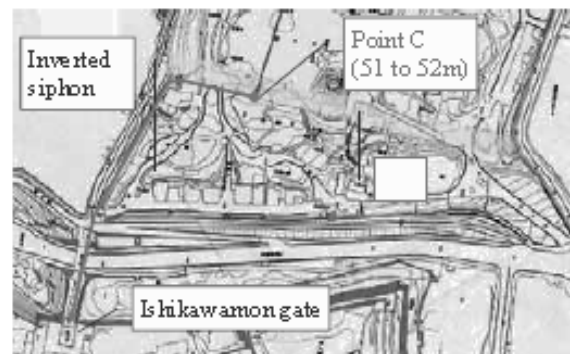


Figure 14. Location of point C

3.5 Fourth Period (between middle 19th century and early Meiji period) and summary

After the magnificent mansion for lord's retirement life was built and the integral utilization of these sites began, the canal changed its appearance as a meandering stream in the mansion.

It can be confirmed that the inlet approaches to the present position as the mansion is removed and the whole area changes to a Japanese style garden based on several drawings at that time (Nagayama, 2006). In addition, wooden pipes used for the inverted siphon were replaced by stone pipes in the middle of 19th century, enabling more stable water supply (Figure 15).

Based on the information above, we can summarize the change in Edo period since the year of 1632 in Figure 16.



Figure 15. Remains of stone pipes near the final point D of the inlet of the inverted siphon in Kenrokuen garden

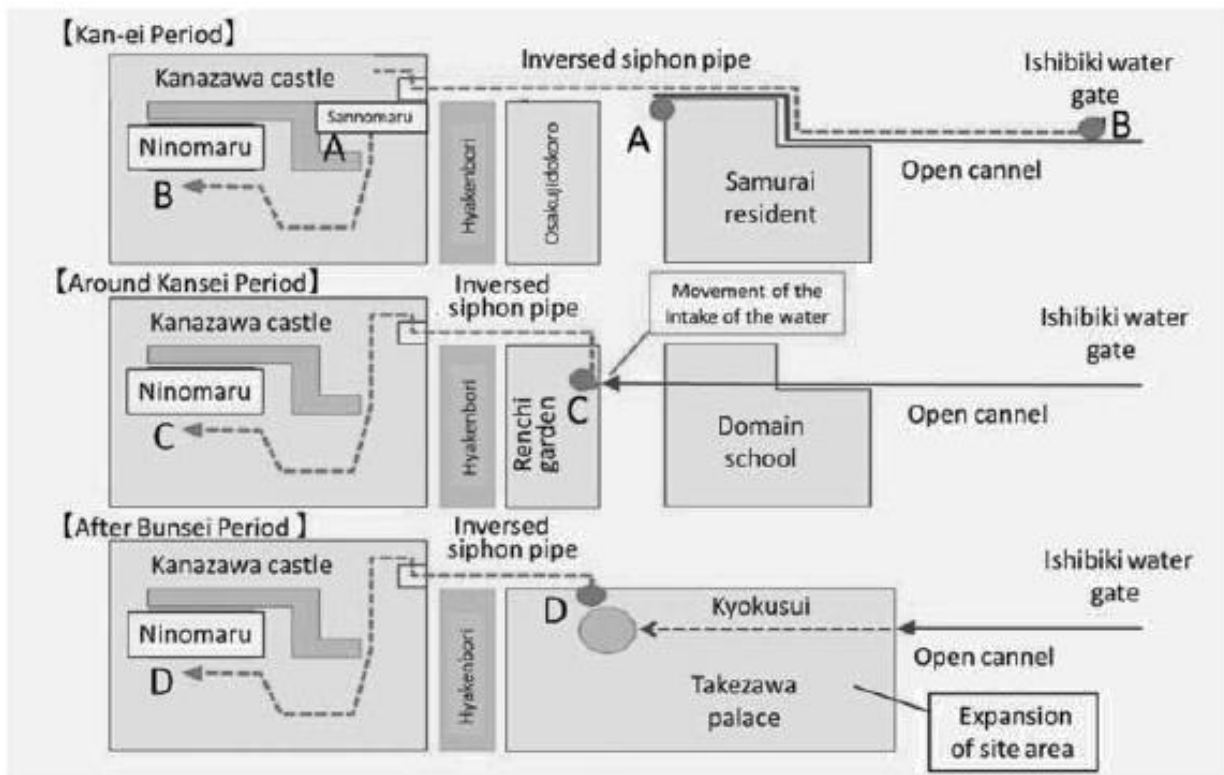


Figure 16. Chronological change of the siphon route of Tatsumi Canal in Edo period

The outcome of this chapter is summarized as follows. The inlet of the inverted siphon which made a supply of water by Tatsumi Canal possible to Ninomaru palace is written in old documents as Ishibiki water gate. However, the exact location of the gate has been unknown. This study identified the location of Ishibiki water gate on the oldest traditional drawing which shows the detailed plan of Tatsumi Canal and is publicized recently (Figure 10). It is clarified that the pressurized pipe length for the inverted siphon in Kan-ei period (around 1634) exceeded 1 km considering the identified location of Ishibiki water gate. Chronological change of the location

of the inlet of the inverted siphon is summarized schematically in Figure 13 considering the land use change in current Kerrokuen garden area.

4. CONCLUSIONS

In this study, the authors extended reviews on unique characteristics of Tatsumi Canal from the standpoint of sustainability of the canal. A new finding is obtained by a detailed inspection of a drawing called “Tatsumijisui esujino ezū” which is the oldest drawing to show the whole route of the canal and was drawn after 1799 big earthquake in Kanazawa area. It is edited by the chief engineer of the Kaga feudal government with memos on damage and restoration projects. By these memos, the reason why the length of tunnel part was increased becomes clear to prevent damages to open channel sections by slope failure.

The inlet of the inverted siphon which made a supply of water by Tatsumi Canal possible to Ninomaru palace is written in old documents as Ishibiki water gate. However, the exact location of the gate has been unknown. This study identified the location of Ishibiki water gate on the oldest traditional drawing which shows the detailed plan of Tatsumi Canal and is discovered recently. It is clarified that the pressurized pipe length for the inverted siphon in Kan-ei period (around 1634) exceeded 1km considering the identified location of Ishibiki water gate. Chronological change of the location of the inlet of the inverted siphon is summarized schematically considering the land use change in current Kerrokuen garden area.

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