(translated by Matsuki/ ver. 100802)

“FLOOD RISK MANAGEMENT”

Japanese river engineering in the 17th century

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1. Introduction

Water conforms to the shape of its container and opens our eyes. Water is convenient to float boats and rafts. Water moistens farmland and nourishes everything. One drop of water must be highly respected.

Meanwhile, flood cost so much by collapsing mountains, washing farmland and carrying houses away. Against such natural disaster, we can do nothing but moaning. Mission impossible is metaphorically told to stop flood by hands. However, it is quite important to prevent flood disaster through yearly maintenance of rivers and reservoirs which are transmitted from generation to generation.

I have studied how to construct and maintain river facilities in Japan. On this occasion, I would like write down the knowhow and publish it, titling ‘Flood Risk Management’ as a chapter of “Farmer’s Common Sense”. Farmers have been in charge of management of dikes, irrigation and riverbank protection since the beginning of ancient rice cultivation. If we forget to pay attention on it today, our children had to suffer from flood disasters.

2. River dike

All of major rivers in Japan have a number of tributaries which has its origin in a deep mountain. Small streams meet together to be a river. The river runs off into the sea, forming a wide waterway between large dikes. A river close to the mountains has aggressive fast flow. A river far from the mountain has gentle slow flow and deep riverbed. A river of fast flow has gravel riverbed and a river of slow flow has sand or silt riverbed.

A dike is a defense wall for our paddy and houses. That is quite important just like a castle wall of warriors. Warriors have considered how to build moats, embankments, fences and towers through much experience of attack and defense. An excellent designer builds a castle which can defeat much enemy, but an unskilled designer builds a castle which is occupied by fewer enemies. These depend a great deal on preparation.

An excellent engineer can build a dike that never gets breaching at the protection area against any excessive floods. Even though bank-full water exceeds the dike, you never allow breaching using your hands while half/full day of the flood peak. Many floods are at the peak half/full day after heavy rainfall. The rainfall continues maximum 2 days and a hazardous flood continues about 5 hours only. With your hard work for flood fighting, you would see water lowering.

A double line dike is recommended along a major river. You should ensure a wide space between the embankments for paddy. This space will be floodway and the second embankment will prevent outflow. If you select a single line dike, you should widen the floodway. Because a wide waterway flows gently but a narrow waterway flows deeply and violently.

You should build each embankment on a sufficient basement area with gentler slopes and a wider crown. A steep slope dike is fragile against water seepage. A narrow crown constrains flood fighting activities such as sandbag piling or tree throw-in. You should design the dike size with the river scale in mind. A thick embankment can sustain against overtopping water or autumn storm. These are important not for a solid dike to hold against colliding water, but for a resilient dike in weakened flow.

Where water flow attacks a dike directly, you should weaken the flow impact with gentler slope on broader basement. And you should reinforce the dike by piling work, wickerwork and riprap. At water colliding front, you should put additional protection of fascine embed, layered gabion, random piling or picket piling with wickerwork.

The best material for earthworks is sticky soil, secondly pebbly soil, thirdly sandy soil, fourthly gravel with sand. Dike built with loose soil is difficult to maintain, however, it depends on earthwork skill.

Fascine-embed is a slope protection. It forms an alternative layer of bundled twig and soil, which looks like a hen’s wing. Although fascine bundle layer on the riverside slope takes time to get stable and decays to shrink in a few years, the dike is tough against bank-full water. Without fascine-embed, you could not shut out a current of a river. A new earth dike may get failure only in 5-7 years. This is a method for a large scale dike.

Turfing is a surface protection. Turf grows up soon and covers the riverside slope. This method is for a small scale dike, because it needs many labors and much turf.

3. Riverbank protection

Riverbank protection is preparative work to prevent dike breaching. At a water colliding front, ordinary river flow smashes the dike surface and scours the foot. The dike is slenderized gradually to be breached. If you mound up earth on outside of the bank, the river course would shift into the dike and erode it more violently. In such case, you should weaken the water flow by protection works on both sides of the river, strengthen the dike itself and change the water course with sand-fill on the scouring. Otherwise stronger flood flow would make the dike more hazardous. These protection works have to be completed before flooding.

For riverbank protection, there are a number of methods: deflectors, box frames, pile sleeves, fabricated oxen, willow/bamboo planting and turfing. If you make effort for many years, you could preserve your paddy and houses from flood disaster. No attention will cost you agricultural harvest and precious land, as a total surprise. Stay alert through the year even at a small valley or river, or you will lose much. Repair any damages on the waterway and maintain the protection works. This is a key lesson for the sustainable life around a river.

Even though you complete river works, activities while flooding takes much cost for labor and material. You should draw up a map of riverbank protection site, write in the dike length, the water colliding points and location of the river management facilities, estimate necessary manpower for flood fighting actions section by section, allot each section to a resident group living in the supposed inundation area, inform all residents of each role by field signs and dairy conversations, and mobilize them for dike protection even late at night.

Much more, a river manager of the state is never in attentive for disaster prevention. You should put top priority to obey his order, go into action as soon as possible and protect the dike. All of river managers, community leaders and neighboring groups have to hold the highest responsibility on it. Confirm your role on an action plan, discuss the matter among residents and strengthen the defense for your community.

3-1 Box frame

Box frame is a shield of the riverbank. Stone-filled wooden skeletons are embedded on the foot of riverbank at water colliding front of a convex bank. It has not to be separated from the riverbank.

Its proper material is something resilient to decay under the water. Chestnut, cypress, zelkova and camphor are the best but precious. Pine log is also usable. One box size, which has 4 or 6 meter square normally, is decided to resist against water colliding power. You should place a series of boxes on the riverbank around low water level and fill and cover it by stone. Otherwise, you should put it on the riverbed in parallel to the dike and also fill the intervening pace by pile and stone.

The box flames can be applied as a spur dike. You should design the spur dike as its head downstream and the root upstream, so that the frames weaken both high and low water flow not collide on the main dike. Too strong water flow may break the structure and scour riverbed around it, which will terrify the dike stability. Otherwise too strong structure might reflect the water flow toward the opposite riverbank. An engineer, who can encourage a smooth water flow with a single spur dike, is respected as the master of riverbank protection.

You should ask for old resident's suggestions. Beside people isolated from a river cannot build even a small dike, people living along a river know well about the nature of their river. Men, women and children of riparian communities are good at not only swimming but also dike building. Therefore they are a good judge of dike conditions and a flood fighter to prevent breaching. People living in coastal area are also so familiar with tidal flow that they are good fishermen to capture fish, shell and seaweed.

Box flames have a wide range in size but a common building process. Instead of stone material, you can use sandbag to fill reinforced frames with crossbars and wickerwork. Bamboo or wisteria is good for the wicker. And you should put riprap around the frames to prevent scouring.

3-2 Deflector

Deflector is one of riverbank protection built at a hard colliding front or a control point to change the water course. The structure is a low dike sticking out from the riverbank. It has a wide range in width, height and length according to the water flow conditions. Then you should build a deflector as the lower head downward and the higher root upward.

When a deflector resists so stiffly against the flow, its whole structure will be broken. It should be built by bundled fascine or gabion. Small scale box frames or fabricated oxen should be installed around the head part. Random piling, wickerwork and riprap are needed in a torrential flow. You should make flood flow overpass a low and flattened deflector on a wide basement. Key point is “never resist stiffly”.

Deflectors are effective on a stone-bed or sand-bed river. But it cannot work well on a fine sand river due to scouring around the structure. In any case, you have to check and repair the deflectors after every flood. You should control sedimentation of the river, which has wide riffles after deep pools. Pools eddy and swirl by submerged rocks or buried logs.

A too long deflector make the water flow attack the opposite bank, and a hard protection on opposite pushes back it to your side. It is important to draw a broad-spectrum planning.

3-3 Gabion

Gabion is a tough structure for riverbank protection. That is a long woven basket made of spit bamboo. Its length and circumference can be adjusted to the protection site. The basket stitch is loose enough to insert stone materials. Wisteria, ｉｖｙ vine, thinly-split lumber are usable as the basket to hold stone.

You should place gabions on a water colliding dike, under eddy current in a torrential flow or on a riverbed to protect the dike foot. You can pile up gabions as a dike. If stone is not available, you could not use a gabion. But a sandbag is usable only for temporary works. You should make a long gabion like a long bamboo strainer. Gabion is most effective for a stone-bed river. On a sand-bed river, it may sag due to the permeability but it works in immediate diversion or emergent flood fighting.

3-4 Pile sleeve

Pile sleeve looks like a sleeve of warrior’s armor. It is convenient to weaken river flow. The structure consists of 5-10 piles in a line on riverbed-to-riverbank, which are combined each other with triple/quadruple crossbars and bundled fascine fastened up by wisteria. You should put a pile sleeve heading downward and prop sticks to support it. A key point is to moderate the water flow, not to repel it. Simple structure made of pile log or any timbers is effective enough.

3-5 Fabricated ox

A fabricated ox is a unique technique of a three-bone skeleton. Any kinds of log are usable. The basic structure has A-shape face of two logs and a backbone of a long log. These are jointed at the top, by wisteria knotting or hinge connection.

You should put a sandbag/stone cap on the head, bamboo/fascine skirt around the body and a gabion shoe on the three legs. Depending on the flow strength, you can put a troop of 3-5 oxen on a water colliding front.

You should install them in an urgent work instead of box frames or pile sleeves. It is effective on stone-/sand- riverbed. Wisteria knotting is better than hinge connection. Fabricated oxen along a diversion channel can stabilize the river course to save labor cost in total. Fabricated oxen also can perform as makeshift random piling. Its strength is fully dependent on engineer’s technique. There are a wide variety of designs in each river.

3-6 Willow/bamboo planting

Willow planting is the best method in riverbank protection. However, so many kinds of willow are in the field that you have to survey which is effective. You should select and plant riverside willows densely, which has low height, many branches and thin leaves. Then prune the branches of willows in autumn to find a quantity of burgeons in next spring. If you leave them for years, the willows would grow fatter and cause turbulent flow to wash the dike surface. If you maintain every year, thin branches with much leaves will lie down to cover the dike in flood flow. Moreover, well-managed willow will promote soil sedimentation around them and strengthen the dike.

When building a new dike, you should plant willow cuttings. In autumn you cut a willow branches into 30-40 centimeter length, by sharp blade of a chopper not to evert the bark. And bind them and put the bottom ends into water to make them rooted. In winter, after picking small planting holes on the dike by a stick, you bury the half of cuttings, and tilt them toward downstream. You will find much burgeons in spring. Another method, to use willow for riverbank protection, is to drive willow piles for riverbank turfing.

Never plant a high-type willow which may put damage on the dike in stormy winds. No tree should be planted on a dike. Marshy plants can grow up well at waterfront. An old theory tells that water fosters a tree and a tree conflicts with soil. Their root will decay after deforesting to make water paths in the dike. Alnus trees are not good as the willow. Well pruned soft bamboo is good but hard bamboo needs caution.

Moles living in a dike often uplift soil. To harass them, you should plant gardenia trees. Foxes and badgers may excavate their burrows in the dike. You should clear overgrowth willows or bamboos not to veil the ground surface. Remind that Willow/bamboo planting must be maintained as a riverbank barrier.

3-7 Turfing

Turfing is necessary after building or thickening a dike. Winter/spring is better for turfing but summer/autumn is worse. Among many grasses, foxtail grass and wiregrass are good to fix the ground surface. Besides that, silver grass, kangaroo grass, cogongrass or sedges, which diverge so much and grows tall, fix a quite limited area. It is good for riverside wasteland or overflow dike to save soil from flood.

You should put terrace-fringe turfing for a new dike of sticky soil to prevent rain-driven soil erosion. The dike will be covered by grass in the end of the spring. For a dike made of sand and gravel, you should select overall turfing although it needs a large amount of grass. Otherwise the dike would be eroded by rainfall. After turfing you should mow the meadow as hay, or tall grass will weaken the dike. On some ground out of use should be covered by vegetation not to lose the land by floods.

4. Flood Management

4-1 Flood forecasting

In the beginning of flood, a river carries surface soil in the catchment area, coloring slightly browny with less foam. While swelling, the water gradually discolors into dark brown with much foam, dirt, refuse and thatch. Then it gets warmer in summer and cooler in winter. You should study preliminary vegetation in upstream valleys, because the native trees in deep mountains have different branches and leaves from that in the plain. You can understand the flooding situation through the continuous observation.

A catastrophic flood is caused by half-/full-day heavy rainfall after two-/three- day continuous precipitation. All water in the mountain and the plain come together at once. That time, unusual leaves come first and the water changes muddy. So you can predict the flood swelling. Flood from valleys expands rapidly. In the peak of flood, much dirt and refuse run through. You can take preparative actions with careful flood forecasting.

Even in the case of large river, large discharge doesn’t come without heavy rain on upstream mountains. And even if no rain falls on downstream area, heavy rain on mountains would often causes floods. In general, it is called that chestnuts comes first in flood. Not only chestnut tree but many mountainous trees are different from plain trees.

At the end of a flood, only small size leaves come with no foam. The water looks transparently. Recessing water is far different from swelling water.

In this timing, you should stick bamboo markers on the riverbank to record and analyze the flood level.

4-2 Flood fighting

Flood fighting works require many kinds of implement so that each resident’s item should be discussed in advance. Those are hoes, sickles, choppers, axes, sledgehammers, straw carriers, yokes, ropes, cables, bamboos, straw bags, straw mats, torches, lanterns, etc. Without hoes you could not clear grass off and rustle soil up. Without sickles you could not cut bushes, split bamboos and cut ropes. Without chopper you could not sharpen piles. Without axes you could not cut trees. Without sledgehammer you cannot drive piles. Without straw carriers and yokes, you could not remove soil, stones and sandbags. Without ropes you could not bind up sandbags. Without cables you could not throw trees into the flow. Bamboo is to be woven to wrap up sandbags and to pick up floating objects. Straw bags and straw mats are to cover the dike slope. Torches and lanterns are preparation for night work and beacons are preferable.

Tree throw-in, a basic technique, is a complementary dike slope protection with evergreen trees of luxuriant branches with exuberant foliage. Before flood peak, you should cut such trees, anchor them on the dike with a strong cable, and then throw them into the flow. You should cover the weak point from downward to upper by a number of trees. Pine trees, cider trees and also bamboos are good. Cover the dike slope by bundles of five/ten trees.

Where flood water overflows the dike, you should dispose fabricated oxen to weaken the flow. When flood water overtops the crown, you should bank up sandbags, straw mats and all materials you can arrange. It is the crucial battle.

Heavy rainfall does not continue all day even in the case of a historical flood. It is told that the mountains and the sea will merge together after 6-hour rainfall of 6-meter visibility, however, even a hundred years old resident does not know such rainfall. Therefore 3- or 5-day rainfall hardly causes a catastrophic flood. Through only 6-hour flood fighting can avoid devastating losses. Although you lose your house and woods, you should protect the dike and preserve harvest of the year which will avoid starvation.

All residents living in an inundation area have to keep a mind of flood fighting through the year. Before the next flood, you should prepare a sufficient quantity of thin rope and thick cable. You should conserve woods and bushes for emergencies. Without such attention, you would lose your excellent paddy and ancestral mansion. Without hard flood fighting, you would lose your wife and kids. Without preparative river works, you could not protect the dike. In addition, you cannot go home for meal during flood fighting operation. You should bring rice, wheat or millet with you.

4-3 Vegetation preservation

You cannot devastate thatch, reed, turf, forest, grove or bush. You should allow outflow at a dike blanketed by vegetation. You never allow overtopping at the usual colliding point because the outflow may make a diversion channel and wide disaster. One solution is to distribute flood flow at non-colliding front. Another is to build overflow dikes, which has thick willow or grass on resilient sticky-solid soil. You should maintain glass on the dike and make wide outflow here and there. And be careful that the leeward side water gets higher in the storm.

You have to maintain forest, trees and bush, because you cannot take action with insufficient materials for tree throwing, piling or wickerwork. Woods and bamboos in the distance or in small amount are unhelpful for flood fighting. Forest conservation is a common-sense of riverside residents.

4-4 Floating objects

There are many bridges over small and large rivers. Floating objects, such as woods, bamboos, timbers, dirt and refuse, often jam on the piers, uplift the deck boards and force the bridge down. You should stabilize the boards by heavy stone, sandbag or timber hook. And you should push away the floating objects by ceiling hooks, long sickles or long rods.

Before the bridge collapses by woods, bamboo, etc, dam-up water threatens both dikes. Always remind that and never forget to place heavy stones at the bridge approaches and to specify borrow pits for emergent sandbag production.

4-5 Activity on the opposite bank

A large scale river has wide distance between both banks and residents cannot hear each other. Especially after dark, there is no sign excepting handy lights. Both side residents make all efforts to prevent flood disaster for own safety. While flood fighting operation, you should observe activities on another side.

In the beginning of a flood, fighting team members scatter on the steady dike watching the river flow. When the dike shows any signals of looseness, they gather at the point and run around busily and carry something faster than before. When they have to give up for overflow water, they will escape into relatively solider zone. Then the water level gets decreased.

At night time, you can observe the opposite side by motion of torches and lanterns. Those gather quickly to and spread from a serious point. Just after the lights escape all together, the water level gets decrease.

It is better to inform each other about weak point of the dike and manpower for flood fighting. A section of less manpower will breach earlier. Therefore you should notify the river manager of the dike condition, water colliding situation and flood fighting capacity. He must recognize all about all villages on a river map and predict the damage on paddy, people and horses. At the worst event, he will judge to breach a dike to minimize damage in total.

Today the dike system has built well and protected by deflectors, box frames and pile sleeves. Therefore residents suffer from fewer outflows, however, never forget that river condition changes continuously and riffle and pool shifts quickly.

4-6 Scouring dragon

Here is a story of Tatsugami deep spot in Kan-ei period (1624-43). A river section, where had not been water colliding front, changed mysteriously into a deep spot. Riverbank protection of deflectors, box frames and pile sleeves could not work well. Gradually the spot got deeper and deeper, making the riverbank protection larger and opposite point bar wider.

Residents felt something strange but the river manager had nothing to do. Then a frogman dived again and again to find a big pine log of 50 centimeter in circumference sticking into riverbed. The river manger asked the length and aspect. But the frogman could not answer.

The river manager made a judgment that the pin log had caused the deep spot, and ordered the frogman to tie a rope to the log. The frogman did it at three positions of the log. Then one hundred residents pulled at the rope to opposite riverside, but the log didn’t move. Five hundred residents pulled at, but the log didn’t move. The river manager and residents were about ready to give up. Suddenly it got cloudy and rainy. Heavy rain fell and water got rise. Then the rope came loose and the log jumped away toward upstream. An old man said “that must be a dragon. It lives one thousand years in sea, one thousand years in river and one thousand years in mountain. Finally it ascends to heaven. It is innocent and nobody can control it.” It was told that the dragon charges the energy in deep water.

Dragon’s waterspout is sometimes seen on the see during evening shower time. In Shouho period (1644-47), a waterspout rose up from Atsuta, strayed around and left for mountain. It was May. Wheat field was squashed out. Forest trees were twisted off. Houses were sucked up and thrown ten kilometer away.

When strong rainy wind comes suddenly, all residents should drive out the dragon wind by shaking long rods and shouting loudly. The reason is that the dragon is guided by a brace of black ducks. If the ducks fly higher, the dragon would follow them, leaving no disaster. In order to distance storms, some residents chase the wind away by waving rods and shouting.

Spot-billed duck is one of black ducks which lives around a pond, a river and a canal through the year. While other duck leave for the north in spring and comes back in autumn, it stays in Japan and hides in isolated deep mountain. Also a dragon, named tailless dragon, lives in the Nikko Pond and spouts water from time to time. To spout much water the dragon emerges from the deep pond. Note that the dragon comes to live in a deep spot and brings you water disasters.

4-7 River facility maintenance

While Manchi-Kanbun period (1658-72), so many floods inflicted a loss on farmland and local economy slowed down. In such situation, it was difficult to prevent floods and to maintain dikes. In the case of major rivers of Kiso, Yahagi, Tenryu, Oi and Fuji, it is impossible to prevent breaching without preparative dike protection works.

Nowadays, rich harvest has recovered local economy in each state. Dikes, irrigations and ponds become well maintained. Less agricultural damage and few drowned people and horses are in each village.

5. Closure dam

Closure dam is built to diverse a river course or to stop tidal flow. To build the dam, you should start banking on shallow parts in the cross section. If you start it at the deep point, the river flow would scour other parts into deeper. It is not easy to supply soil material from borrow pits for such work.

Wide footpaths improve efficiency of soil conveyance. You should arrange smooth mobilization of labors. One idea is to set two footpaths to make a rotating labor’s movement between the building site and borrow pits. Another is to appoint a foreman for each 20-30 labors, like a commander for soldiers. Consider to eliminate vainness and accidents.

For the closing work, firstly, you should drive piles in two lines at upper/downstream of the closing point to fix pontoons. Then set fascine and straw mats on the scaffolds to secure labor’s workability. The width is decided by the labor volume. Never drive piles in the closing section, which may interfere following works.

Next you set anchor piles all around the closing channel and suspend thick cable of bamboo or wisteria to make a broad grid which covers the channel. On the grid, you set bamboo or twig net. On the base above you stitch up a broad bulky carpet of straw mats with two large flanges on upper/downstream end. Then you mount soil, sandbag and fascine all together on the carpet and wrap up them by the flanges into a big soil mattress of 1 meter height. You repeat wrapping after wrapping to make a solidified soil mass of sufficient height for the channel depth. After covering the embankment section with straw mats and tamping it down, eventually, you cut all hanger ropes by pitsaws, axes, and choppers, to sink the soil mattress down. It is important to do it at one time synchronizing with a siren, a drum or chant encouragement. If you miss the timing, the soil mattresses would lose the balance to be flowed away. But, you can do it. To complete river closing, you should set random piling with underwater wickerwork on upper/downstream old channel. You put sandbag and soil and tamp it hardly. Although water still flows under the soil mattress, objects from upstream will fill the waterway gradually. Soon you plant grass, millet and turf on the embankment. Never default patrols, or the closure dam may get breaching in several months.

In addition, about the tick rope suspending, you cannot put too high tension in it to be broken. And hold extra length in both sides because heavy soil mass pushes the hanger ropes down. At the last stage, the mesh is close to the riverbed.

5-1 Diversion for Atsumi Shinden

In a case of the closure dam at Atsuta Shinden in Bishu State, the closing point is in tidal flow area of a large river coming from Shinano and Mino State. The dam building and the diversion excavation were wart was conducted only in a couple of days using all farmers in the state. The project in Keian period (around 1650) had a purpose of paddy field development and it was done successfully, because the land had very fertile soil made from estuarial reed bed. Also irrigation system is working well and farmers harvest abundant rice every year.

5-2 Diversion for Fukawa Shinden

Fukawa closure dam in Hitachi State diverted a river. The construction was done without problem in the former articles. However no tax rice was paid and the project manager was criticized. It was out of matter. New paddy was gained but no farmer cultivates it earnestly. The reason was that there had been much paddy and fewer farmers in the state. And their agricultural skill was not well. The failure was caused by not construction work but immigration policy.

5-3 Diversion of Yahagigawa River

About 60 years ago, Yahagi River came from Shinano State and went in Mikawa State through a narrow segment at 10km downstream form Okazaki. The channel of the section had 600m in length and only 60m in width. This constricted portion uplifted the level of flood water for 8km upstream and caused many beaching on both side. The flooded water attacked many villages to destroy houses and kill residents. In Keicho period (1605), the river manager of the state succeeded in changing the river course to the west. It was told that farmers in the state build the dam 60 years ago but nobody remembers the details now. The new river channel gets degradation of 3m in the 60 years. Willow trees, which were planted on the riverfront, are now standing on the riverbank slope. Other willows and bamboos, which were planted at the water edge of each period, stands in some lines.

Around the new river mouth, sand bar has spread out over 10km and the quay has been inconvenient. The river has gravel-bed in upper and sand-bed in downward, covering solid sticky soil in the ground

Major rivers in Mino State have gravely riverbed in upper, sandy riverbed in lower and silty riverbed around river mouth. Rivers running into the Pacific in Tokaido region, named as Yoshida, Tenryu, Oi, Abe, Fuji and Sakawa, have only gravely riverbed. Upper mountains of them are close to the ocean. Rokugo, Kuji, Kinu rivers have gravely riverbed in upper and sandy/silty in lower. Mioka, Kumode, Tosei, Ina and Miya rivers in Ise State have gravely/sandy riverbed.

5-4 Diversion of Kizugawa River

Yodogawa River and Kizugawa River had got diversion a long time ago. The earthwork was unique. Firstly hundreds of boats, which loaded full-volume of soil, were sunk down to stop the flow. After the new channel developed, the boats ware dug out. The rivers, Yodo from Omi and Kizu from Iga, flow through Yamashiro and Settu State and run out to Namba Sea. Around the sea it has gentle flow and sandy or silty riverbed. Upstream Seta valley is always rapid because the Biwa Lake never stops water release.

Rivers in Japan have uncountable number of origin streams in the mountain. These meet together again and again to form a large channel. While flooding, tidal waves also rise to the river. Flood water and tidal waves fight against each other. Then the water never decreases its level and breaches the dike to wash paddy and houses. Around river mouth, severe water disasters occur many times.

5-5 Diversion near Yokosuka Habor

Yokosuka Harbor in Enshu State was developed at a river mouth, which has small river flow and small tidal flow. The harbor was so shallow that vessels cannot enter or leave. Therefore the harbor manager often tried to dredge the navigation way.

The river had two river mouths, one is Yokosuka and another is Fukuda. Before Kanbun period (1660-72), Yokosuka channel is the trunk, however the major flow has been changing to Fukuda channel. Today’s main flow goes to Fukuda and also harbor function has shifted.

Building method of a coastal dike is different form a river dike. There is no total solution because tsunami waves or earthquake waves have too big power. Only one way is to build a dike leaving a wide blank space between the sea water. Build it in wide shape with grassing, bamboo and willow planting. Put random piling with wickerwork, fascine embed and riprap protection. However, these protection works will be eroded by sea waves and vegetation will be blighted by tidal wind.

6. Typical engineering

6-1 Coastal dike

A coastal dike to prevent tidal inundation is different from a river dike against river flood. High tide washes the dike slope and salty wind blights turf and bamboo on it. Slope protection of fascine embed, gabion and riprap will be degraded in a few years.

You should build a dual dike system. The anterior dike breaks waves and the posterior prevent tide overtopping. You should design the anterior dike low and wide to break waves, and the posterior as a strong river dike. A single dike cannot withstand extreme sea waves that have far larger power than river flood. Even in a sunny and breezy day, sea wave can be violent beyond your expectation and attack the dike to leave damage. Wave must be higher under adverse weather.

Storm brings heavy rainfall that may cause internal flood on paddy fields. Outer sea waves can be higher than inner flood level. You cannot protect the coastal dike which is attacked both sides. Once salty water intrudes into paddy, little rice grain may survive. Once saline water covers paddy, all rice must decay to be disposed. You should install sluiceways into the dike, and set gates on the both sides. Then you should operate and maintain the wooden gates that will degrade soon due to estuarine borers.

After tidal flooding on paddy fields, you should discharge all inundated water as soon as possible. However, if you breach the dike in some sections, rebuilt parts would have vulnerability for the next storms. If you discharge water using the sluiceways, it would take several days and rice will go to ruin. You should select breaching point in advance and conduct preparatory work such as turfing the dike and stocking stones. While/after breaching intentionally, you have to rebuild the dike immediately even in the midnight when the weather turns bad. Coastal dike management is very difficult.

6-2 Tsunami flood management

In Kan-ei period (1624-43), tsunami waves hit Mikawa State and wash away people, horses, houses and rice harvest after a typhoon south wind in September. An old man told that the tsunami had three waves and the second was the biggest among them. And all casualties were killed the receding wave.

In Hitachi State, many people were also killed by three tsunami waves. People said that the secondary biggest wave came after/before the smaller wave from the south.

In 1680 September, Enshu State was hit by three tsunami waves after south stormy wind. The biggest second wave reached in front of the castle. Villages were flooded and three hundred people were dead.

Over one hundred years before that, in the middle of 16th century, this state was hit by similar tsunami and lost over one thousand people. Their graves were kept up to now. In such case, ebb tide of tsunami easily destroyed a solid dike away. No one can prevent it. Then the state governor checked the tide record and built memorial mounds in coastal villages in Kanbun period (1661-72). After that a local governor built life-mounds, an evacuation center, to ensure village to living in tsunami-prone area.

Many severe floods occurred in many states in Manchi-Kanbun period (1658-1672). Heavy rainwater in mountainous states run through valleys to be a large flood of major rivers of Kiso, Yahagi, Yoshida, Tenryu, Oi, Abe and Fuji. Bush and reed ran as chained-rafts on dike-full flow. Ten thousands of large uprooted trees, which cannot be removed by three hundred labors, run into the sea whole a day. These objects were pushed back to the shore by southern wind and pulled up on the beach by people. Then high tide surge in September came and washed away all trees. People living in the coastal area should observe the sea everyday and understand feature of the high tide. After two or three calm days, a large swell came from the offshore and invade into the beach with wind, as an old fisherman said.

6-3 Flashflood prevention

Flashfloods comes from mountains into a plain in a short period. A torrential flow rushes into several colliding points, scours riverbed and riverbank, destroys mountains to build landslide dams, and finally breaches some dikes to wash paddy and to leave sand and silt there.

You should moderate and let through the flood, using tree throw-in and timber barricade. Against outflow you should divide the flow and drain water to protect paddy, using small reinforced dikes by bamboo, willow and turfing. Remind that flood from well-wooded mountains lasts longer and flood form woodless mountains passes quickly.

Flashflood comes just after intensive rainfall on the upper mountains, even though the channel usually has less discharge. Inattention brings damages. Flashflood flows quite torrentially like a fall so that the channel has stone-/sand-bed. You should set gabions or box frames before rainy season. Flashflood changes its water courses frequently by sedimentation. A paddy higher than the river becomes poor-harvest and that lower than it becomes rich-harvest.

6-4 Riverbed excavation

Rocky riverbed excavation is sometimes conducted to adjust a river course. You can crack hard/soft rock by pickaxes, harpoons, chisels and sledgehammers to remove rock blocks away with a hanger rope. You should excavate it from downstream side because it is easy to wash the cracking site by water. If you start it from upper side, more labors would be needed to dispose water and debris. Sometimes you can diverse a river flow and conduct dry-up works. On rocky field there are few farmlands so that river excavation can get rapid progress using adequate methods.

Sandy riverbed is easy to excavate. You can get on a boat and remove riverbed sand to both sides by handled-plates, hoes and spades. Deeper channel has stronger traction force. Up-to-down straight work is recommended not to make a shallow riffle section. In a less-water river, you can wait swelling. It is easy to do.

For swampy river, scrambling method is not effective. In flowing channel you can use sweep hoes. In flow-less channel you have to dig up mud by spades. Dry-up method is applicable only for small rivers. There is no other way for large rivers. It cost much labors.

7. Water Resources development

To build a rainwater reservoir, you should solidify its basement and prevent intensively water flow through gravely or sandy ground. Especially there is deep gravel and sand deposition under a former riverbed, where it is not easy to stop water infiltration which may cause dam breaching.

To keep full water level, you should made a spillway at solid soil section and allow overtopping. If it is not so solid as to be eroded quickly, you put random piling with wickerwork and fascine embed on the spillway channel. Also you should protect the reservoir side slope by fascine embed and shrub embed method.

A new dam is often broken by water seepage after first water elevation. Such operation should be executed in winter season which is agricultural off-season. In summer and autumn, farmers are very busy. As mentioned above, sticky soil is the best material and gravel, sand or loose soil is worse. However you cannot build the dam without using available materials at the site.

If you select improper topography for a pool or a pond, you could not impound water. Moreover breaching water may cause rice washing-out and silting-up on paddy.

A pool is to be ditched and embanked around a spring or a wetland to impound four-season water and to distribute it to paddy.

A pond is almost same but built on a hollow area.

A dam reservoir checks a current of a river to gather rainwater on the catchment area for irrigation. An embankment, dried out in a season, often cracks.

7-1 Irrigation and drainage

Irrigation and drainage channels are indispensable for paddy fields. You have to maintain them through the year. Even in winter, farmers pour water on wheat in some states and pool water on paddy to debug. Without enough channel capacity, you could neither irrigate paddy nor drain rainwater. If you default to clean and repair the channels in autumn, you had to cost more in winter.

Irrigation and drainage channels are fundamental infrastructure of your paddy. The irrigation channel charges water to soften the paddy in spring and supplies water to planting and fostering in summer. In autumn, drainage channel disposes water dispose water before harvest. You should keep each other not to drop a lump of soil into channels. To keep smooth flow, you should stop dropping anything in and pick up every refuse out of the channels around your paddy. If you hesitate to do so, your community would fall into some water troubles.

You never narrow channels intending to widen paddy area. Water system is the first facility for rice production. When rice wants to grow up, you should widen and shallow the irrigation channel to supply warmer water. When rice is suffered from drought, you should blind the irrigation channel to supply cooler water. You should design channel alignment not to go through behind trees and houses. Plant bush clover, reed, cattail and iris around the trenches. Put turfing but never plant bamboo and willow on dikes. Investigate earth quality and prevent failure of a thin dike of 2-3 meter in width. You should monitor the dike section to find water seepage.

7-2 Reservoir

A rainwater reservoir is built by dam embankments. You should select a hollow land and estimate inflow volume, or you cannot storage sufficient water. You should design irrigation channel higher than the paddy for water delivery, and keep away from gravely/sandy ground to minimize water leakage. In addition, you cannot carry water through marshy field.

A new dam cannot stop infiltration for 2-3 years. You should monitor and solidify every year. You should tamp down sticky soil in the initial embanking and never use fascine or sandbag which will harm the dike in future. At a sloping valley, you should design a series of stairway dams to reserve much water. A standing-alone dam can reserve little and cannot keep balance.

When you set a sluiceway, you should compact soil tightly under and beside the structure. One idea for monitoring is to insert detective objects, which is different from soil material such as another soil, charcoal, ceramics or wood chip. You can check any damages on the structure. Cypress, camphor and resinous pine are good for the sluiceway.

You should arrange the sluiceway at the central part of the valley and extend it out of the embankment, not to make the outlet flow injure the dam. You should set intakes at several elevations to release cooler bottom water in a drought or warmer surface water in a rainy season.

After withdrawing water from a river, you should attach a 10-meter additional gutter on the sluiceway and guard the intake, because you can hardly reconstruct it. Then fabricate two/threefold shielding gates to shut off water and control it by a laborsaving hoist gear over the water. At the outlet you should arrange random piling and fascine embed not to get scouring. Besides the intake build up two tall posts as a locator and harden around the gates by sandbags. If you don’t prepare, you would suffer from many incidents.

7-3 Ditch

There are many spring spots around highland and at plain-edge in a valley. Around them, you should dig ditches and embank dikes to supply water for your paddy. While long-lasting sunny days, you can pour the last water from the ditch network and pray for rain to prevent land split. You have to keep rice roots alive, or plants cannot revive in the next rain. The water is like a medicine for a man near to death. One drop of water saves one ear of rice, and one grain of rice will generate ten thousands grains next year.