Rail Baltica

RBDG-MAN-016-0109

Design guidelines

Railway substructure, Part 2 hydraulic, drainage and culverts

20-06-2022

Co-financed by the European Union
Connecting Europe Facility

Table of Contents

1. Regulations, Codes, Standards and Guidelines

The principal international code employed for the design shall include, but not be limited to, the following:

- UIC719R: Earthworks and track bed for railway lines
- API Recommended Practice (RP 1102) steel pipeline crossing railroads and highways
- Culvert design and operation guide (CIRIA C689)
- Manual for railway engineering – Volume 1 – Track – AREMA - 2016

2. General principles of design

The design of hydraulic structures shall take into account the constraints related to the project:

- Climate: wide range of temperature, snow, etc. Winter is characterized by snow and frozen streams. During the spring, ice and snow thaw, creating ice drifts and spring floods;
- Design speed of HSL requires safe systems for passenger safety;
- Elevation of the water level during winter (called "ice dams")
- Presence of bog areas with permanent water,
- Underground water level near the surface,
- Navigable waterways requiring clearance for ships,
- etc

For embankment structures, the studies relating to the crossing of thalwegs or watercourses should define the highest water level (HWL) in the floodplains, the design and dimensioning of the hydraulic crossing structures and the measures to be integrated into the design to protect against the effects of erosion.

Where the railway runs in cuttings, the studies of the water catchment areas crossed lead the design of the hydraulic drainage system. These factors are dependent on the geotechnical studies (soil types, conditions of drainage, zones defined as geotechnical risk before being drained, etc), on hydro-geological studies (presence of water tables in cuttings) and on studies on the protection of sensitive groundwater.

It is also beneficial to limit the risks of flooding as far as possible and to introduce compensatory measures along the line, as well as reducing the overall environmental impact (flood water movements etc). This should be seen in terms of:

- initial design of valley crossings made at the outset of the study phase (flood flows, landscaping etc),
- need for the drainage of cuttings to be by gravity only to ensure flow continuity (no low points) and thus reduce the risks to train movements.

Design criteria are completed by typical cross section of drainage and culvert in embankment and in cutting.

Hydraulic and drainage improvements, which include cuttings, embankments and railway track formation, shall be designed and constructed for a useful life of hundred (100) years due to the impact that any repairs would have on operations. No substantial reinvestment has been earmarked for hydraulic and drainage improvements or infrastructure during this period.

Due to forecast of long operational period for each railway structure, Designer must prepare necessary description of maintanance works for each hydrotechical structure to keep the same parameters as they will be proposed in the design stage.

This long design life cycle shall be taken into account when choosing appropriate technical solutions.

3. Hydraulic calculation

3.1. Peak flow calculation

The methods for flow estimation should enable calculation of flow for different periods, among which, at least for ten years (Q10%) and one hundred years (Q1%) return periods and for several catchment area surfaces. For major spans, these should also enable an approximation to be provided for the extreme flood level. They should be based on measurements made in the catchment area or at least in similar catchments. For larger crossings, an estimation of the extreme water level should be made.

It is strongly recommended that local methods should be applied to estimate flood discharge in accordance with local regulations. The local methods are well adapted to the local meteorological conditions.

Peak flow calculation should integrate all relevant and up-to-date climate data: rainfall, snow melt, ice melt, …

The method of determination of peak flow depends on the availability of hydrometric data:

- For a measured watercourse, with sufficient hydrometric data:

  The peak flow for a given exceedance probability is estimated on the basis of a statistical analysis of the available flow data. The representativeness of the flow data series depends on the length of the records available in relation to the return period considered.

- For a measured watercourse with insufficient hydrometric data:

  Data from analogous measuring stations is used to supplement the available data. A statistical analysis is performed to ensure an adequate correlation between the hydrological characteristics of the investigated river and the river used as a benchmark.

- For an unmeasured watercourse: the peak flow is estimated using regional formulas (derived from a statistical analysis of data from local measuring stations). In this case, the 'Rational Formula' is applicable for a catchment area which is equal or less than 20 km^2

$$Q = \frac{1}{360} \times C \times I \times A$$

where,

Q : runoff (m3/sec)
C : runoff coefficient

I : rainfall intensity (mm/hr)
A : catchment area (hectare)

- Runoff Coefficient, C

The runoff coefficient varies with land use type and condition, soil, slope and rainfall duration. The runoff coefficient to be adopted along the proposed alignment shall be according to local practice.

- Rainfall Intensity, I

Rainfall intensity supplied by the local meteorological bureau shall be used.

- Catchment Area, A

Catchment areas shall be defined and measured from topographic surveys and maps with scales of 1/50,000 or 1/25,000. As a final step, the catchment areas shall be checked at scales of 1/5,000 or 1/1,000.

- Time of Concentration, T_c

This is the time of flow from the farthest point on the watershed to the outlet. It is the cumulative travel time of overland flow and stream flow from the catchment area to the outlet point.

The time of concentration varies according to the shape and slope of the watershed, the rainfall intensity and the physical properties of the stream channel. The time varies inversely with rainfall intensity, so the estimation of time is difficult. Hence the value of average rainfall intensity when used in the Rational Formula will affect the accuracy of the result. One method is proposed to estimate the time of concentration.

The time of concentration is expressed as follows:

$$t_c = t_o + t_s$$

where:

to: time of overland flow (travel time of flow from watershed boundary to stream)

ts: time of channel flow (travel time of overland flow concentrated into recognizable channels from upstream to the outlet of watershed)

The velocity of overland flow (V) ranges about 0.3 ~ 0.6 m/sec. The travel time of overland flow (to) can be calculated by slope length (L) divided by velocity (V). The passage of overland flow into a channel can be viewed as a lateral flow. Using the cross-section, water surface slope and roughness coefficient at various points along the channel, the velocity can be calculated by Manning's Formula and the time of channel flow (ts) can be estimated.

The minimum time of concentration shall be **10 min** for drainage design.

In case of several methods available, the most restrictive will be used.

If required by local administration, peak flow calculation should take into consideration the effects of climate change.

3.2. Water carrying capacity calculation

3.2.1. Simplified approach

The Manning's Formula shall be used to define all the flow parameters of culvert at preliminary stage and drainage sections as follows:

$$Q = A \times V \text{ with } V = \frac{1}{n} \times R^{\frac{2}{3}} \times S^{\frac{1}{2}}$$

where:

A: cross-section area (m2)
V: the average velocity m/sec
n: roughness coefficient

$$R = \frac{A}{P}$$

R: the hydraulic radius (m),
P: the wetted perimeter, m
S: the water surface slope

The coefficient values for roughness as defined by Manning to be used for crossing structures are defined in Table 1:

TABLE 1. ROUGHNESS' COEFFICIENTS

Material of drainage	Roughness coefficient, n
Natural bed	0.025 - 0.05
Earth ditch	0.033
Rock cut	0.025
Concrete on-site ditch	0.016
Precast concrete U ditch	0.016
Reinforced concrete pipe	0.013
Box culverts in prefabricated reinforced concrete or poured in situ	0.013
Ductile iron pipes	0.011
Pipes or draining box culverts in vitreous earthenware	0.01
Pipes or draining box culverts in thermoplastic materials	0.01

3.2.2. Detailed approach

For culvert in detailed stage, the hydraulic analysis shall include calculation of flood routing of the waterway up to the bridge site, backwater analysis, scouring analysis of piers and foundations, freeboard, minimum water clearance, optimum span and flow area contraction ratio.

To have a complete view of these criteria and interactions, all culverts and bridges positioned for hydraulic reasons shall be hydraulically verified using an appropriate tool. Hydraulic tool should be able to define water surface and velocity upstream, inside and downstream of the culvert/bridge. Designer is responsible for the final choice of the tool in accordance with the specific issues and project risks.

3.3. High Water Level in flooded area

In flood plain, top of sub ballast layer shall be place 1,50 m over HWL. Slopes are protected against risk of erosion in the event of water circulation along the embankment. Elevation of the ebankment must consider potential height of the waves generated by the wind.

If required by local administration, volume of water fill by embankment should be compensate by extra volumes to maintain initial water level.

4. Under track crossing structures

The hydraulic crossing structures should enable:

- the crossing of large valleys and rivers and their floodplains;
- the passage of water coming from the natural watersheds (streams, dry thalwegs) from one side of the line to the other or from the discharge of the longitudinal drainage system.

Hydraulic structures will be essential to cope with each and every depression in the natural terrain (ephemeral watercourses and thalwegs) that may have significant water flows, albeit temporary.

This section deals with structures for natural flows. Pipes connection between one side to the other side of the track are described in the longitudinal drainage chapter. Any water coming to the HSL, concentrated in river, ditch, thalweg or depression, shall be guided under the track without risk for the railway.

The types of structures and works could be:

- engineering structures with a hydraulics function, designed by engineering team,
- small structures consisting of a pipe (circular piping or rectangular pipe), end heads, a setting bed and an embankment adjacent to the pipe.

Other than their hydraulic role in the transit of water to the sub-track cross-ducting, these structures can be used for:

- reconnection of access roads (especially in the case of engineering structures with a hydraulics function),
- service gallery for ducting irrigation pipes,
- passage for pedestrians,
- passage for animals.

Concentrated water arriving to the railway at the top of cutting slopes must be limited to small catchment area and connected to drainage by water down feed (see drainage chapter).

4.1. Project flow

The project flow (Qproject) shall be defined in order to be able to calculate the apertures and size of the hydraulic crossing structures. Values shall correspond to the water level for a 1 in 100 years return period event (Q1%) [or probability of above-maximum floods of 0.1% (Q0.1)] or a known historical flooding record level (Qhistoric) if this is greater.

4.2. Special requirements

Special requirements for risk areas

In risk areas, the behaviour of the structures should be verified in relation to an exceptional flow referred to as 'extreme' (Qextreme) so as to ensure that there would be no risk to the safety of people in the event of malfunction or obstruction. In the absence of other data, this extreme flow is considered to be equal to 1.8 times the 1 in 100 years return flow (Q1%) [or 1.8 times the probability of above-maximum floods of 0.1 % (Q0.1)]. Designer should propose list of structures to whom such requirements will be applicable.

For the 'extreme' flow, if the water level, water velocity or water surface can create disorders on the HSL, major roads, dwelling, …, opening shall be enlarged.

Special requirements for navigable water courses

For navigable water courses, the size of the structure shall take into account the specific navigation water level, clearance and navigation constraints. The current navigable water level should be defined in accordance with local regulations.

Special requirements for ice

The size of the structure shall take into account clearance for ice drift for the project flow (Q1%) water level.

Special requirements for new roads along the railway

New crossing structures under new major roads located just upstream or downstream from the railway shall have the same design parameters as the adjacent crossing structures under HSL over the same watercourse.

For new minor roads, new crossing structure under road shall not hamper the hydraulic conditions of the crossing structure under HSL.

4.3. Sizing of crossing structures

Design of crossing structures shall comply with the Environmental Requirements of Rail Baltica, with a minimum that the project cannot introduce any significant effects on existing situation.

4.3.1. Major structures

This concerns structures whose aperture is two meters and larger than two meters.

Major structures can be definite:

- according national norms/regulations,
- any natural waterway,
- any drainage crossing with dimension 300mm and more,
- polder structure or part of that,
- area of protective dam,

- Forest land drainage systems.

The crossing of large valleys and floodplains should be studied for their hydraulic characteristics with the aid of mathematical or physical models in either steady or unsteady state. The modelling together with the field investigations should make it possible to define:

- The highest water level;
- The dimensions of the structure or structures;
- The impact of the project on the flow characteristics and on the environment at construction completion as well as during the interim stages.

These hydraulic studies shall be carried out by qualified and licensed consulting engineers recognised in the particular field by the appropriate authorities.

The design of the structures shall fulfil the following objectives:

- The main river channel, if it exists, shall be disturbed as little as possible. The minimum aperture of the crossing structure should, therefore, be at least equal to the width of the main river channel.
- The level of the soffit for the bridges shall be designed to be at least 1,5 m above the highest water level calculated for the project flow (passage of debris, ice drift) so as to reduce the risk of blocking up.
- For box culverts, a minimum clearance of 0.50 m shall be respected so as to reduce the risk of obstruction through blockage. For circular culverts, the water level should be limited to ¾ of the internal height of the pipe.
- In accordance with legislation, where there are engineering structures, roads, buildings, houses or farming lands, it is necessary to check that these are protected against backwater from the projected structures. Efforts shall be made to ensure that the structure will have no negative effects on existing properties. Maximal of water level elevation induced by culvert is limited to 5 cm in area with dwelling or existing infrastructure and 20 cm for other areas.
- The structures shall be of the right size for the project flow, and a check on their proper functioning will be carried out for intermediate flows (Q50 for example).
- The protection of piers and embankments adjacent to the structure is to be included in the studies. The embankment protections should be designed to be at least 1,5 m above the highest water level in case of risk of ice impact on structures or 0,5 m over the highest water level in other cases.
- The regulatory structure clearance constraints relating to navigation shall be respected.

In addition, other constraints may emerge and be imposed during the studies carried out on the aquatic environment in conjunction with the laws on the Environment:

- respect for spawning ground zones,
- access of fishermen or land animals, maintenance of natural materials on the hydraulic structure ground sills,
- preservation of the options of the morpho-dynamic potential of the river, etc.

4.3.2. Minor structures

These are structures of the pipe and box culvert type whose aperture is smaller than two meters.

The 1 in 100 years return flow (Q1%) or an historically recorded flow (whichever is the greater) is to be used in the design.

Minor crossing structures under the High-Speed Rail Lines should respect the following rules:

- The positioning of hydraulic structures at each low point of the natural terrain is compulsory where significant runoff is expected under flood conditions (even if temporary as in the case of ephemeral streams).
- The flow should be free surface flow for the project flow under steady state conditions. Methods for water level calculation in the hydraulic crossing structures should be compliant with local standards and chap 3.2.
- For box culverts, a minimum clearance of 0.50 m shall be respected so as to reduce the risk of obstruction through blockage. For the circular value, the water level should be limited to ¾ of the internal height of the pipe.
- The flow velocity for the project flow is limited to 4 m/s.
- Certain structures, in particular those located in low-elevated areas or in cuttings that present a risk for the safety of passengers in the event of malfunction or obstruction (drain blockage, flood or related problem). Their hydraulic characteristics shall be tested systematically for extreme flows (Q extreme). This extreme flow shall be considered to be equal to 1.8 times the 1 in 100 years return flow (Q1%) [or 1.8 times the probability of above-maximum floods of 0.1 % (Q0.1)]. If the test shows a water level attaining the track bed (track level) or generating threshold effects on the surrounding (submersion of embankment, risk to the safety of persons, etc..), the dimensions of the structure(s) should be increased.
- As for major structures, the backwater of the water level upstream of the structure shall be limited to protect people and buildings near the project.
- Structures crossing a fish water course: specific facilities to adapt to the particular kind of fish.
- Any drainage solutions for connections of existing drainage systems under railway track crossing shall use casing pipes not less than 300 mm. Designer shall propose maintanace solutions for such crosings.

The use of bridge box culverts and siphons shall be exceptional. If it is not possible to avoid bridge box culverts and siphons, they shall be supplemented by the necessary securing structures against the risk of track bed flooding.

4.3.3. Structures used as passages for small fauna

The design of the structures shall take into account the morphological characteristics of the water course being crossed as well as the length over which it is covered by the railway line, meeting the requirements described in the chapter Wildlife under structures in document RBDG-MAN-027 Environment.

4.4. Design Criteria

4.4.1. Major structures

Provisions with regard to the construction for major structures are given in RBDG-MAN-017.

4.4.2. Minor structures

Hydraulic structures shall be installed at each low point identified in the topographical surveys, and at the crossings over natural run-offs.

The recommendations for the skew (angle between HSR axis and hydraulic structure axis) are between 60 and 140 gon (54 to 126 degrees) for ordinary pipes and between 80 and 120 gon (72 to 108 degrees) for rectangular pipes. If the skew of the watercourse is greater than this, diversion of the watercourse shall form part of the design, placed downstream of the HSR line.
The minimum nominal diameter (ND) of the railway cross-ducting pipes for natural waterways is 1 000 mm (for drainage pipe, refer to drainage part). The minimum aperture for box culverts is 1 x 1 m.
The minimum class of resistance for pipes is 135 A (in line with European standards).

The minimum nominal diameter for road cross-ducting pipes is:

- 1 000 mm for main roads (highway),
- 600 mm for second category roads,
- 400 mm for small roads with very low traffic.

<u>Foundations</u>

The seating shall enable correct hydraulic adjustment of the base of the culvert and provide a supporting arch to distribute loads. It shall be sustainable so as to avoid any risk of erosion, gully formation or stagnation of water under the culvert.

<u>Pipes and box culverts</u>

The nature and the class of resistance for the pipes as well as the possible use of box culverts depend on the following conditions:

- Supporting ground;
- Stable terrain: box culverts, reinforced concrete structures and pipes in reinforced concrete or with inner tube in steel;
- Compressible terrain: hydraulic structures are subject to special provisions (substitution, calculated cambers, etc ...);
- Minimum and maximum heights of cover;
- The choice of type of structure is mainly based on the height of the embankment that covers it. When the minimum cover depth for circular structures cannot be respected, the used of reinforced box culverts should be considered;
- The slope shall be such that the maximum flow velocity in the structure should not exceed:

- 3 m/s for structures consisting of multiplate pipe culverts or corrugated steel pipe without concrete base (a concrete slab should be provided when there is the risk of abrasion of the metal by materials transported along the water course bed);
- 4 m/s for all other structures;
- Less in case of fish crossing.

For pipe without reconstitution of natural bed, it shall be checked that the minimum self-cleaning speed of 0.5 m/s is achieved for a quarter of the design flow rate.

Depending on the speed at exit of the structure, additional arrangements may be required (head, stilling basin, stone blocking, dissipators, etc ...).

In line with this, designer should present the way of approach deemed appropriate for the calculation of the mechanical resistance of the ducts needed together with the main criteria to be adopted vis-à-vis the requirements laid out and listed in this document.

The minimum classification of resistance for the ducts shall be 135 kN/m2 (with reinforced concrete).

Reinforced concrete pipes shall be installed preferably.

Headwalls

Minor hydraulic crossing structures shall include a headwall at each of their ends so as to:

- Protect the embankment from erosion.
- Improve the hydraulic gully conditions,
- Connect the structure to the drains upstream and downstream (geometry, altitude).

All the various headwalls shall include a cast in-situ cut-off wall, compulsorily poured in situ and in contact with natural ground. This shall be cast in-situ without formwork. This restriction applies also to prefabricated headwalls.

The zones between a concrete structure and earth structures should be protected against erosion:

- Upstream: wherever there is a risk of erosion upstream of the structure, protection should be provided. When there is the risk of obstruction in the structure due to floating debris, a retention system should also be provided. It should be placed sufficiently far upstream so as to allow for free flow in the structure.

- Downstream: protection against erosion should be provided depending on the flow velocity at the exit of the structure.

This consists of a facing wall, side walls, a ground sill and a cut-off wall. It is in reinforced concrete.

The head facing wall is always perpendicular to the pipe or culvert axis.

The types of downstream protection are described below:

- either a stilling basin.
- or stone blocking (or small rubble filling) placed on an anti-contaminant geotextile.
- or a semi-circular dispersal regulator created using riprap blocks in order to damp the run-off flow speed. These riprap consolidations shall be installed on an anti-contaminant geotextile, or filter layer.
- or a riprap reinforcement in a stream or ditch.

The following zones shall be coated in concrete:

- upstream and downstream of a hydraulic structure, with lateral discharge channels forming a junction, as well as the part located between the hydraulic structure and the junction.
- the linking ditch between 2 adjoining hydraulic structures.

<u>**Embankments contiguous to hydraulic structures**</u>

Embankments contiguous to major hydraulic structures (engineering backfills) are described in Cross Sections.

Installing hydraulic cross structures without contiguous embankments is prohibited.

4.5. Component products

The following provisions are requirements in the event of employing the following component products.

Use of plastic pipe (PVC, PEH, PP, etc) for culverts is forbidden.

4.5.1. Circular culverts in reinforced concrete

Circular culverts with a resistance classification of reinforced concrete (200 kN/m2, 250 kN/m2, 300 kN/m2) and with a very high resistance (median metal sheeting) shall be defined and subjected to qualified manufacture with certification provided by the main contractor.

The use of circular piping in non-reinforced concrete is not permitted. The cutting of pipes is also prohibited.

The use of elements of a different class of resistance is prohibited within the same hydraulic structure.

The minimum cover height for pipe is 1 m between the hydraulic structure and the bottom of the sleeper.

4.5.2. Box culverts

These culverts are calculated on a case by case basis and shall have a minimum cover thickness greater than 0.50m measured from the outer sealing surface to the underside of the lowest sleeper (tie).

These structures are to be made of reinforced concrete. This may be either poured in-situ or prefabricated.

4.5.3. Corrugated metal culverts

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Steel bolted corrugated metal culverts are not allowed under main railway line.

The use of multi-plated metal culverts beneath rail embankments shall be limited to those with compressible soils.

The thickness of the sheets is determined as a function of the diameter of the culvert, the depth of the cover and the risk of corrosion and abrasion.

Assembly by interlocking of two sheets or by riveting is not permitted.

Corrugated steel pipe shall be internally and externally coated with a sacrificial metallic coating and protective organic coating.

Steel carrier pipes shall be protectively coated and provided with electrical insulation or a cathodic protection system.

5. Stream courses diversions

Two types of diversion may be encountered:

- temporary diversions, for the requirements of site work phasing,
- permanent diversions that should only be used when no other solution is possible. In this case, downstream diversions should be preferred.

Any diversion will be ruled out for flow rates exceeding 50 m3/s.

The natural watercourses should be maintained wherever possible. However, if the skew of a hydraulic structure is too great and/or if the route of the new line crosses the same watercourse at several points, it may be necessary to divert this runoff away from the works.

Diversions shall be placed outside the limits of the right-of-way.

At no event should the works result in a modification to the river course in level or slope outside the worked area. The proposed diversions should be validated by the appropriate water management agencies and shall take into account the possible hydro-morphological developments found in a thalweg or a valley. At no event should the works entail a modification to the line of flow either in level or in slope outside of the worked area.

In the case of a diversion parallel to the new line, a minimum distance of 4 m shall be respected between the fence along the line and the edge of the nearest bank. Risk of erosion or flooding of slope of embankment is analysed in case of overflow of the derivation.

Proposed development work shall take into account the environmental characteristics of the water course (fauna, riverside vegetation).

The cross profile of the new channel shall be as similar as possible to that of the water course to be diverted.

Protection against the erosion of the banks and the channel bed should be provided, in particular, in line with the curves and changes in slope.

6. Protections of structures against erosion

Protection measures should be incorporated against erosion in areas where there is an acceleration of the flow (when flow velocity may tear off soil or embankment particles), wave action, the risk of impact (for instance: slump-with-root drift, ice drift). This, essentially, concerns the approaches to the main hydraulic structures: i.e. the foundations to the structure, river bed around bridge's piers, banks and base of embankments, connection of ditches.

The approaches to hydraulic structures in the floodplain should equally be concerned, newly created canal banks put in place for diversions, and, occasionally existing banks with stability problems and where the flow is locally accelerated.

Protection measures regarding the canal banks, the foot of sloping structures and the foundations of the construction work primarily consist of:

- riprap,
- gabions or similar rock matting technology,
- vegetal growth in the case where there is no risk to the stability of the line.

Other alternative solutions (interlocking prefabricated elements, synthetic or natural coverings, composites, etc.) may also be proposed depending on special requirements or local practices.

Minimum level protection is maximum level (HWL, top of wave, top of ice block) + 50 cm.

Protection works against the water erosion related to the culverts and bridges shall be verified using the results of a modelling and specific equation in order to evaluate the length of the riprap/gabions aprons and the diameter of the rocks.

All the protection works against the water erosion related to the embankments shall be verified using specific equations in order to evaluate the diameter of the rocks.

Separation layer (sand, geotextile) is placed between natural ground and riprap or gabions to prevent slope erosion. The choice of the best filter to use in the protection works shall be made taking into account the flow and soil features.

6.1. Riprap

These are protective structures using rock blocks at the foot of slopes, rampant and banks to prevent erosion associated with run-off flows.

Besides the main body of riprap, the rockfill bulk shall include:

- between the riprap and the slope, a filter intended to retain fine materials within the slope; this may be replaced by anti-contaminant geotextile installed in one or two layers depending on the conditions of installation of the riprap,
- a footing block (anchor) to mitigate any general tendency towards the lowering or undercutting of the channel.

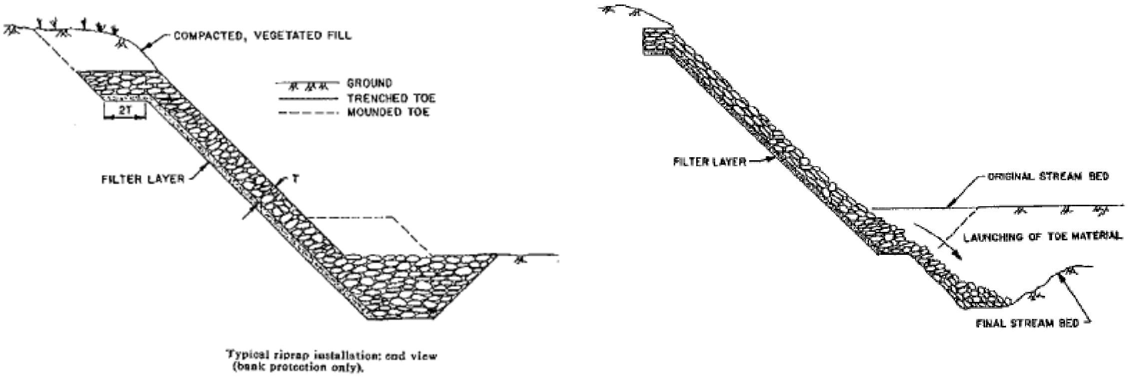

Figure 1. Typical riprap installation and evolution (extract from AREMA chap 1)

Rocks are not fixed by concrete to move with river bed deformation.

Rock sizing shall call on a recognized method as AREMA approach or ISBACH method.
Specifications for rock material for rip rap are described in RBDG-MAN-015 Railway substructure Part 1 embankments and earthworks.

6.2. Wire-enclosed rock or gabions

These are blocks of smaller dimensions than those used for riprap, combined together in a mass within a parallelepiped metal grill armature.

Generally, gabions are more suited for high flow rate or very steep slopes.

They shall, as a matter of obligation, include a foundation slab consisting of flat and deformable gabions (or Réno mats) capable of adapting to deformation in the channel/bed.

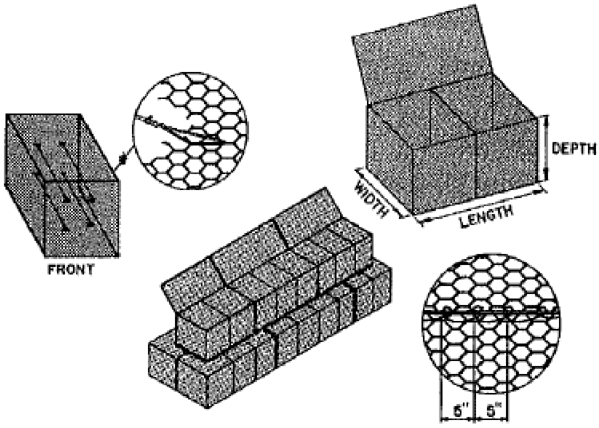

Figure 2. Gabion basket fabrication (extract from AREMA chap 1)

Cages are engineered from double twisted hexagonal woven steel wire mesh heavily galvanized to provide long term corrosion protection.

Specifications for rock materials for gabion are described in RBDG-MAN-015 Railway substructure Part 1 embankments and earthworks.

6.3. Plant engineering

The creation of a structure using a planting technique should take into account the following constraints:

- The scheduling of works in accordance with the biological seasonality of the plants used,
- The fragility of the structure at the early part of its lifetime. This disadvantage is compensated for by the use of biodegradable geotextiles that reinforce the structure until the plants are well-established,
- Surveillance of the structure during the phase of the establishment and development of the plants (2 to 5 years)
- long-term durability regardless of weather conditions

Under railway conditions, plant engineering techniques are prohibited for run-off speeds in excess of 1.5 m/s and under the following conditions:

- Banks under span structures (high risks, lack of space and light),
- Bridge piles (very high risks),
- At the foot of embankments at the level of structures (high risks, lack of space and light).

7. Longitudinal drainage

Drainage system is essential for durability of the track bed. It enables to collect, to guide and to carry away run-off water and underground water along the railway. The drainage network shall perform a quick disposal of storm water applying a minimum transversal gradient of 4% of the top of the sub-ballast layer.

The purpose of longitudinal drainage installations is to receive and/or drain:

- run-off from the track bed into the drainage structure,
- run-off water from slopes and watersheds,
- water seepage from the foundation structures,
- internal water, as appropriate with a view to achieving its downwash (water table, capillary upwelling).

The collected runoff may be conveyed to a local storm drain system, based on the hydraulic capacity or, conveyed to the nearest natural water body, after applying appropriate treatment measures.

The estimation of rain and snowmelt flow rates is carried out by integration of flows originating from drained surfaces: external catchment areas, slopes and railway track beds, platform, ...

Conversely, the presence of water in the structure requires that the drainage system be designed to a suitable depth to lower the water table and drain the track bed.

In cut slope of rock formations, the designer shall evaluate the possibility of any rockfalls. If stone traps are adopted, the design shall meet the minimum requirements specified in RBDG-MAN-015 Railway substructure Part 1 embankments and earthworks.

7.1. Rules for sizing

7.1.1. Hydraulic calculation

The estimation of the project flow is performed by application of methods described previously.

The Manning's formula shall be used to define the size of drainage sections.

The most balanced solution should be proposed regarding each case..

7.1.2. Return period

The sizing of the longitudinal drainage of the High-Speed Rail Line shall be carried out in relation to a return period of 10 years (Q10%) for cuttings and 5 years for the base of embankments where the height is greater than 2 m.

At particular points in the longitudinal drainage system where overflow might result in the risk of problems, dimensions shall be based on a return period of 100 years (Q1%). For example, these special characteristics may correspond to sudden changes of flow direction or drainage narrowing and intercepting cutting drainage.

7.1.3. Maximal permissive velocity

The maximum permissive velocity (average velocity of the channel at normal depth) for drainage channels shall be as shown in Table 2.

TABLE 2. PERMISSIBLE VELOCITY FOR CHANNEL TYPE

MATERIAL OF DRAINAGE	PERMISSIBLE VELOCITY
Earth ditch	Clay = 0,25 m/s Sand, gravels with silt, clay or sand = 0,50 m/s Clean gravels, sandy silt, argillaceous silt = 0,70 m/s Grass = 0,60 to 0,90 m/s Claystone, compact clay, limestone with superficial alteration = 1,1 m/s Molasse, sandstone = 1,20 m/s Compact limestone = 3 m/s
Concrete ditch Concrete U ditch	4 m/s
Concrete pipe	5 m/s
PVC drain	5 m/s

7.1.4. Freeboard

The minimum freeboard between Maximum Water Level (MWL) and top of the drainage for ordinary drainage structures shall be as shown in Table 3.

TABLE 3. **FREEBOARD CRITERIA FOR PEAK WATER DEPTH**

Material of drainage	Minimum freeboard
Earth ditch	0.05 m/ edge of the ditch
Concrete ditch	0,05 m / edge of the ditch
Pipe, drain	25% of the diameter
Concrete U ditch	0.10 m / top of the concrete or soffit of the cover where applicable

MWL = water level corresponding to the discharge for the reference probability of exceedance.

7.1.5. Level of drainage

Channels for longitudinal drainage equipment shall be bedded in order to drain the sub-ballast and the prepared sub-grade layers.

In this case, the drainage elevation is embedded at a minimum of 5 cm under the base of prepared subgrade.

The hydro-geological classification of cuttings is defined according to the position of the water table.

- Cuttings where the distance between the water table and top of sub-ballast layer ("P" point on cross section) is less than 2 m, are classified as "wet cut".
- When the water table is higher than 2 m under point P, cuttings are classified as "dry cut".

All groundwater tables shall be drawn down to preserve the quality of the natural subgrade layers and the stability of the slope. The high-water level shall be drawn down permanently to below 1.5 m from top of sub-ballast layer.

If the groundwater table is intersected by a cut, the design shall take into account the water table lowering effects on slope stability. The design may provide for features such as draining trench, draining blankets or other appropriate measures.

All slope protective measures shall allow free seepage of groundwater.

7.1.6. Low point

Low point in cutting are not allowed. Longitudinal profile of the track shall be adapted to design continuous slope from high point to the end of the cutting.

Accordingly, except for tunnel, pumping stations in cutting are prohibited.

7.2. Choice of drainage system

The type of drainage is to be chosen in relation to each cutting and embankment according to the hydraulic and hydro-geological conditions of the site as well as its geotechnical and local features.

All cuttings shall imperatively include:

- a longitudinal track bed drainage system collecting the runoff from the track and from outside catchments. This drainage shall be supplemented, as appropriate, by a ditch on the top of the slope. The need for this ditch shall be assessed according to the special features of the catchment area (pattern of water flow, major flow rate, environment, etc...).
- a longitudinal track bed drainage system collecting internal water (rainwater that has entered the subgrade and underground water).

Embankments shall not be equipped in this way except to transit water originating from neighbouring cuttings or to collect run-offs from the catchment area.

The run-off from external roads into the railway drainage system should be limited to the flows collected at road bridges or, at most, to the approach ramps of these structures.

Continuity in runoff from all points of longitudinal drainage to an outlet should be ensured. In areas where the HSR drainage connects to an existing drainage system, appropriate structures shall be provided to prevent downstream scouring.

Areas where it is necessry, a chute or step type energy dissipater shall be installed at the connection to existing ditches.

For longitudinal drainage, priority shall be given to open cut layout: earth ditches, lined earth ditches, etc.
Derivation in crest of cutting shall be rare and designed with specific protections to prevent all risk of overflow toward HSL or erosion of slope cutting: over sizing, security distance from top of cutting, protection, …

7.2.1. Open drainage

This type of drainage is earth ditches, lined earth ditches, (the slope being a function of the nature of the soil) or precast concrete ditches (U shape).

The choice between the different types of drainage should be made, case by case, according not only to technical criteria but also to economic criteria, including considerations with regard to earthworks, engineering structures and subsequent maintenance.

Shape, size and slope of the trap should be adapted for water evacuation and sizing should take into account presence of stone blocks filling drainage section.

Recommended longitudinal slope for open drainage is 0.004 m/m. Minimum longitudinal slope for open drainage is 0.002 m/m, and exceptional – 0.001 m/m.

Earth ditch

The speed of runoff in the earth ditches shall remain less than the velocity of erosion of the drain so as to prevent the risk of damage. Above this velocity, the drainage system should be lined.

Ditches have minimum width of 0.50 m and minimum depth of 0.50 m.

Lined earth ditch

Typical linings for earth ditches are grassing, turf reinforcement mats, erosion control blankets, rip rap etc.

The material forming the lined earth ditch shall be capable of sustaining the maximum permissible design flow velocity and negative impact of rain and wind without scour or erosion.

Concrete lined earth ditch

Earth ditch could be lined by concrete to face specific cases. Contrete lining open cut drainage depends on the on-site constraints:

- Geotechnical risks and hazards (dissolving, swelling, …);
- Hydrogeological risks and hazards (karst, …);
- Environmental risks and hazard (environmental sensitivity).

  In each case concrete lined earth ditches are suggested, designer shall submit justified explanation why coated ditches were selected as the preferred option due to any of the conditions listed below:

  - it is the only solution from technical side due to the aforementioned negative aspects;
  - it is the most capex/opex friendly solution in that particular location.

  Equally, it may be lined in order to contain the risk of excessive growth of vegetation in the event of water stagnation.

Ditches have minimum width of 0.50 m and minimum depth of 0.50 m.

Intercepting cutting ditches are always coated and of a minimum slope of 0.004 m/m. Beyond 1%, concrete riprap ditches can also be implemented. Rapid changes in the direction of interception ditches must be studied in relation to head loss phenomena and risks of overflow into elbows.

The concrete coating is poured in situ. Dry joints are provided approximately every 6 m and a 1 cm expansion joint will be implemented filled with silicone every 30m.

The upper elevation of the concrete in the ditch shall be bedded at a minimum of 5 cm under the level of the natural terrain or the level to be drained.

Conrete lined earth ditch shall be avoided in case of presence of water table or frost-sensitive soil.

To limit risk of uprising of the concrete in case of presence of water:

- A layer of sand, or other no water sensitive materials, could be set under concrete,

- The number of expansion joint could be increased,
- concrete could be replaced by geomembrane.

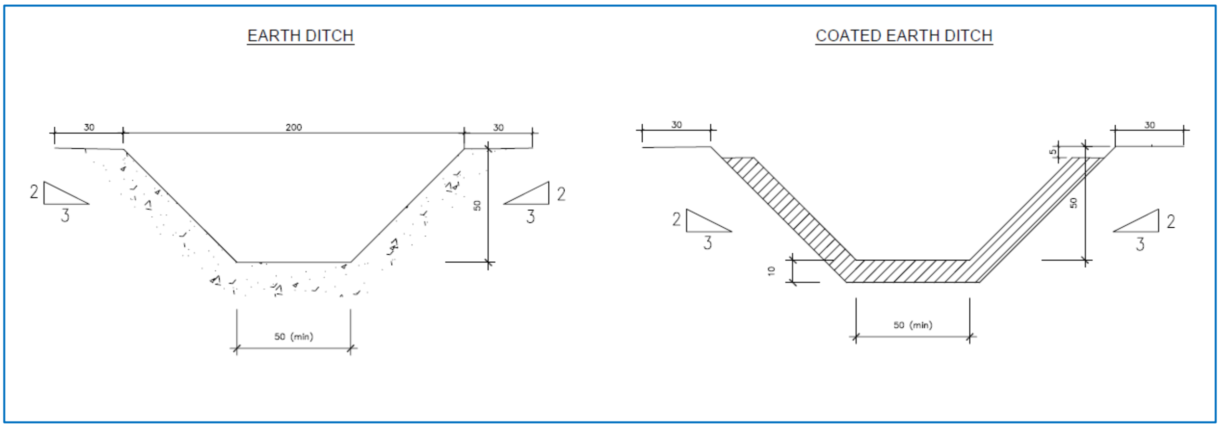

Figure 3. Typical cross section of earth ditch and coated (contrete lined) earth ditch

__Concrete U ditch__

Regarding drainage between two tracks or low discharge in cuttings, prefabricated concrete U-shaped drains may be used. U ditch are wrapped in draining aggregates and geotextile. These have vertical or sub-vertical walls which have to be pierced with weep holes. They should incorporate cross braces and possibly additional prefabricated units where significant depths are to be achieved. The drainage level is the lowest level of the weep hole. Concrete U ditch is relevant in cuttings affected by groundwater

The minimum width is 0.50 m.

7.2.2. Buried drainage

This type of drainage is drains or pipes.

In case of buried drainage inspection hatches must be instaled in the necessary frequency based on the exact type and dimension of the drainage pipes for easy access and maintenance The use of buried drainage is reserved for:

- the collection and the evacuation of internal water,
- the lowering of the water table,
- continuity of open drainage under obstacles (access, over pass, track…).

All drainage devices should be accessible for maintenance. Buried drainage shall include an inspection manhole every 80 m at a maximum distance.

When it is practically unreasonable to ensure 80m maximum values, then:

- Exceptional value of up to 120m maximum distance between manholes could be applied for buried drainage. Designer must submit clear and detailed maintenance description for such cases if such exceptional values will be used.

- Exceptional value of up to 120m maximum distance could be applied for third party buried melioration when it is practically unreasonable to ensure 80m maximum values, without foreseeing manholes in railway infrastructure land plots for third party manholes. Designer must submit clear and detailed maintenance description for such cases if such exceptional values will be used

Lateral drains

Lateral drains may be used for longitudinal drainage of the railway track bed, but only in the event of the separation of surface waters from internal waters. Lateral drains are made of vitrified sandstone or with thermoplastic material, with a circular section showing vents over the whole circumference. The minimum diameter to be used is 300 mm.

The minimum longitudinal slope for a lateral drain is 0.002 m/m.

Lateral drains are forbidden under ditch.

Longitudinal pipes

To enable certain obstacles to be crossed, such as engineering backfills on road bridges, road accesses, the longitudinal continuity of drainage can be provided by non-draining collectors.

The nominal minimum diameter of longitudinal ducts is 300 mm.

In a railway track bed: a longitudinal duct may be considered “in the track bed” where the line is:

- in a cutting, in the zone between the foot of the slopes, or in an embankment contiguous with road bridges,
- in an embankment, in the zone between the peaks of the slopes or under embankments contiguous with rail bridges.

The minimum longitudinal slope for longitudinal pipes is 0.002m/m.

7.2.3. Adjoining structures

These types of structures provide the transition and junction of the different drainage systems, enabling the verification of the correct operation and flushing of the network in place. These shall be walk-in or accessible up to the level of the drainage channel.

Inspection hatches

Circular hatches are installed along the pipes and lateral drains according of local requrements and material suppliers , at each change in direction or diameter of the buried networks. They shall be either prefabricated entirely or in part, or poured in situ; of an internal diameter of 1.00 m, they shall be fitted with a narrowing element at their upper part, itself topped by a locking mechanism (manhole cover in cast iron or grill or gulley trap). They are fitted with forged galvanised iron steps and a grip handle in galvanised steel when the depth is greater than 1.00 m.

Manhole is located out of “danger zone” (area under influence of trains) to access to the drain during railway traffic.

Water down-feeds

Water down-feeds are required for all punctual water inlet coming to railway of top of cutting. They are autostable structures installed on the slopes, either in a cutting or on an embankment, to convey peak water to the longitudinal drainage located at the foot of the slope.

The prefabricated elements in rectangular section concrete shall be sealed along their entire length in ordinary concrete.

7.2.4. Drainage of the cuttings (flow > 2 m3/s)

In the bottom of cuttings, designer shall consider a maximum limit of 2 m^3/s for the longitudinal flow in the drainage so as to avoid the risk of damage or the threat to the durability of the line.

If it is impossible to comply with this requirement, designer will propose a solution adapted to the risk and designed to enable ease of maintenance.

7.2.5. Special characteristics of the drainage

Particular attention should be given to the systems adopted in the transition zones in view of all the special characteristics of the drainage system: dual embankment (with hydraulic constraints similar to a cutting), acoustic protection, drainage between tracks, transition between cuttings and embankments, modification of the nature of drainage.

Drainage at the approaches to road bridges shall comply with all the safety requirements for railway operations.

7.2.6. Particular areas

Particular areas need specific drainage:

- Noise screen. The installations to be used shall be studied case by case according to the structure of the screen, the type of foundation, the constitution of the embankment and the characteristics of the track bed to avoid stagnation of water along noise screen: free passage between top of track bed and bottom of the screen, weep holes pierced through basement of the screen, drainage materials around basement of the screen, gutter, …

- Midway between tracks: in the station and passing track zones, it is necessary to provide drainage of surface run-off water at the low point of the track bed with a prefabricated concrete U ditch. In the hypothetical case of the installation of a catenary pillar in between tracks, a special study must be carried out.

- Transition cutting to embankment with steep slope: a transversal drainage shall be provided collection of water liable to transit longitudinally on and in the track bed of the following embankment, at the interfaces between surface of earthworks/prepared sub-grade and prepared sub-grade/blanket layer. This shall compulsorily be installed in a cutting (see RBDG-MAN-015 Railway substructure Part 1 embankments and earthworks)

7.3. Tunnel and cut and cover

In underground parts, water supply comes from:

- Rainfall:
    - Through open trenches formed by the junction of an aerial part and a tunnel;

  - In mechanical ventilation shafts (insufflation and extraction);

- Runoff: along the walls of structures in communication with the outside
- Infiltrations input assessment passing through walls

Tunnel drainage system shall catch all nature of water and evacuate them outside the tunnel without risk for train circulation.

7.3.1. Return period

The sizing of the drainage in tunnel and adjoining systems (pumping station, tank, gutters, opening, …) shall be carried out for a return period of 100 years.
The behavior of the structures in the tunnel shall be verified with an extreme flow entering in the tunnel. Risk analysis should assess risk for track, signaling, electrical devices, … for extreme flow equal to 1,8 times the 100 years return flow, based on water level, water velocity, duration of contact with water, draining time of low points, …
For this 'extreme' flow, if the water level, water velocity or drainage time can create disorders on the track and systems, drainage opening should be enlarged, or intermediate storage point should be proposed.
Water level shall always be lower than bottom of slab.

7.3.2. Tunnel entrance drainage system

Water will be collected in two points:
- first at the natural ground level, where it can be rejected by gravity;
- second at the entrance of the covered trench, with a pumping station.

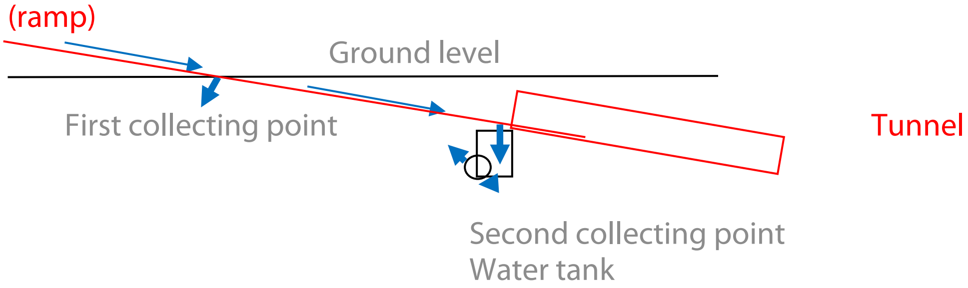

Figure 4. Ramp to tunnel drainage principle

Longitudinal profile shall carry out high point on the track as near as possible to the tunnel entry to limit water tank's volume and pumping station's size.
Runoff water at the surface of the track is collected at first and second collecting point by a transversal channel or by holes at the bottom of the longitudinal drainage and directed to outlet or storage tank.
- At first collecting point, drainage is implemented at the top of the ramp (at the junction between embankment and ground level) in order to intercept water from open areas and evacuate this water by gravity to outside drainage system. The outlet must be sufficient to receive all the water which will be injected inside.

- At second collecting point, drainage intercept water of the open area at the head of the tunnel before it enters the tunnel. The water will be discharged to outside with a pumping station after regulation in a tank.

Water tank is installed under slab level to collect all rainfall water coming from trench drainage system by gravity. Lateral drainage could be opened over tank to let water fall on. These longitudinal waterholes could be protected by grids for pedestrian security.
Storage tank is designed to store water waiting for release outside the tunnel with low discharge value (compatible with receiving environment) (see basins chapter).

7.3.3. Tunnel body drainage system

The drainage system comprises:

- a central collector equipped at least every 90 m with manholes with removable collars and a ballast retaining grid,
- side channels positioned in the shoulders connected to the central collector.

The following are not authorized:

- drainage systems under the base slab,
- systems which cannot be visited,
- longitudinal drainage under the track.

Rabbets (width: 100 mm - depth: 80 mm) are to be made in the roof and sidewalls transverse to the construction joints on the covering, to facilitate drainage of any water infiltration.
The central manhole should have a minimum dimension of 0.6mx1.0m that will facilitate the visit and the maintenance of the drain.
Minimal transversal slope of the slab is 1% toward gutter(s).

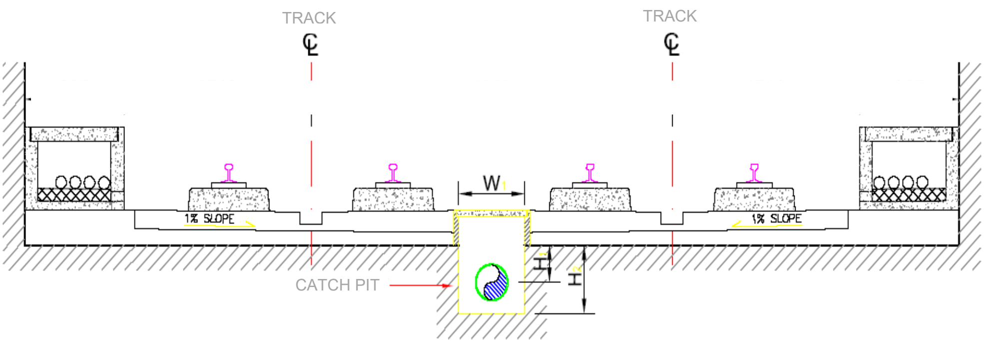

Figure 5. Example of typical drainage in tunnel

Infiltration input assessment is function of water input passing through walls. The calculation approach for estimating the volume of water flow to be evacuated, which will function of

- the flow rate which passes through the wall (l / day / m²);
- the contact area

The following method can be used to estimate water infiltration flow of surfaces. It is based on the following formula:

$$Q = q \times SA$$

With:
q: specific flow of the walls (l / m² / day)
Q: Total flow rate through the wall (l/ days]

SA: total molded wall area (m^2)

Dewatering structure will be installed at the lower point of the tunnel to evacuate water entering the underground system. Pumps to be installed in each dewatering structure shall be sized considering the infiltration water inflows.

7.3.4. Pumping station

The following requirements apply to any type of pumping station.

Designer should evaluate real necessity of each pumping station before submission of such solution.

A pumping station is composed of necessary type and number of pumps (minimum 2 pumps) and water tank storage.

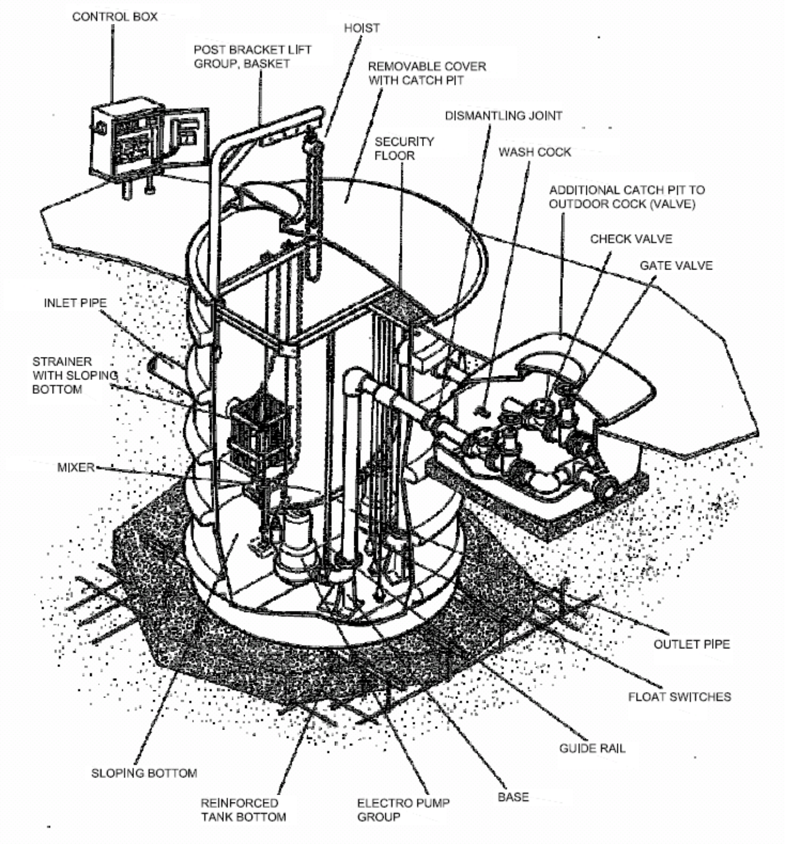

Figure 6. Standard Pumping station configuration (source: KSB pumps Guinard)

Pumping station should include:

- materials of pumping station equipment must be according requirements of the local norms, necessities based on the chemical aggressiveness of the pumping station environment (water, soil and ect).
- Water tank storage to reduce effects of the water peak flow by storing water for 100 years events and regulate the start of the pumps at less than 15 starts / hour. It has to be located under the level of the track.
- Pumping system: it is composed of a minimum of 2 pumps operating alternately to limit the risk of technical failure and to reduce the power requirements at the start of the pumps. It is recommended to use submersible pumps.

- Warning system: to turn on and off the pumps in conjunction with the water level within the storage and the alarm system. The warning system should be protected against vandalism and flooding and connected to global railway monitoring system. The panel has to be installed higher than the highest predicted water level.
- Remote control system: to connect the pumps control system to the OCC in order to have at all time the status of the system (pumps surveillance, level of water, power supply).
- Power requirements: It is required to evaluate an alternative power source in case of failure of the primary power source and connection with the alarm system. Designer should evaluate necessity of diesel generator as emergency power unit. If it is not possible, it is recommended to set-up a system that will detect when the water level reaches the track bed level.
- Pumping station access: Road access should be provided as much as possible as it will be required for maintenance reasons. Access should allow for replacement of pumps, unless adequate infrastructures are provided through the tunnel. Jib crane should be provided with sufficient capacity to maneuver pumps and other equipment such as generator.
- Ventilation of pumping station: to provide a ventilation system capable of compensating for the air pressure caused by the pumps and providing fresh air income.

Regular maintenance operation of pumps, pipes, valves, water level detectors, power supply, control, box, ect is required to ensure correct operation. In case of pump station necessity, Designer should provide detailed description of maitanace works for pumping station.

7.4. Electrical plant (sub-station)

Electrical plants shall be protected against risk of flooding due to internal water (runoff on the surface of the plant) and external water (catchment area intercepted by the plant).
Electrical plant is drained by ditch or buried drainage system to prevent risk of flooding.
In case of runoff coming toward the electrical plant, a ditch intercepts the flows upstream of the sub-station and bypasses it to prevent the water from entering into the plant. In case of potential high water level according to 100 years return period, possibility to raise the substation elevation should be evaluated.
Internal and external drainage are designed for 100 years return period.

7.5. Materials

Characteristics for aggregates for seating, embankment contiguous to hydraulic structure, embankment and pipe materials are detailed in RBDG-MAN-015 Railway substructure Part 1 embankments and earthworks.

8. Water releases

After collecting runoff and underground water by drainage system, it can be necessary to laminate and/or treat water flows before discharging in the natural environment or the urban rainwater network. Specific devices will be described to respect hydraulic compatibility of water releases with final receptor.

8.1. Global approach

The hydraulic compatibility of the final receptor shall be verified in term of quality and quantity, in natural area and in urban areas.

Conditions and authorizations of release of water into existing network or toward water courses or water surfaces should be obtained from the network administrator or the environmental authorities. If necessary, treatment and lamination installations should be designed to respect the maximum outflow and particles threshold limit values.

In case of connection on existing network, the dimension of the network shall be verified if it is enough to accommodate the design discharge.

A sensitivity analysis of the natural environment should be carried out in order to identify and classify all particular areas in terms of sensitivity (water surface, Natura 2000, abstraction of drinking water, …). On the base of this analysis, nature of treatment shall be defined to protect urban and natural areas adapted in line with level of protection required.

Nature of treatment for quantity of release could be:

- No discharge
- Retention of surface water runoff: basin, vegetated ditch
- Storage basin based on infiltration (design to be checked considering winter conditions)
- …

Nature of treatment for quality of release could be:

- concrete ditch or channel,
- oil interceptor,
- sand filters or sand trap,
- containment pond with stop valve,
- …

Sensitives areas defined by EIA shall have specific treatment in complement of basin as track waterproofing.

8.2. Detention/Retention of surface water runoff

8.2.1. Description

The objective of the retention basin is to regulate peak discharge of rainwater into the natural or urban environment. Rainwater peak flows are temporarily stored and gradually restored to the natural or urban environment.

These are grassed ponds emptied completely in a few hours.

Basin consists in:

- An inlet structure connected to the drainage devices of the railway infrastructure;
- A storage volume;
- An outlet control structure with a calibrated orifice for controlling the leakage rate;
- A safety spillway to evacuate flows for events greater than the basin sizing period;
- A maintenance trail around the basin and an access ramp at the bottom of the basin allowing access to the basin, inlet and outlet devices for maintenance.
- A fence.

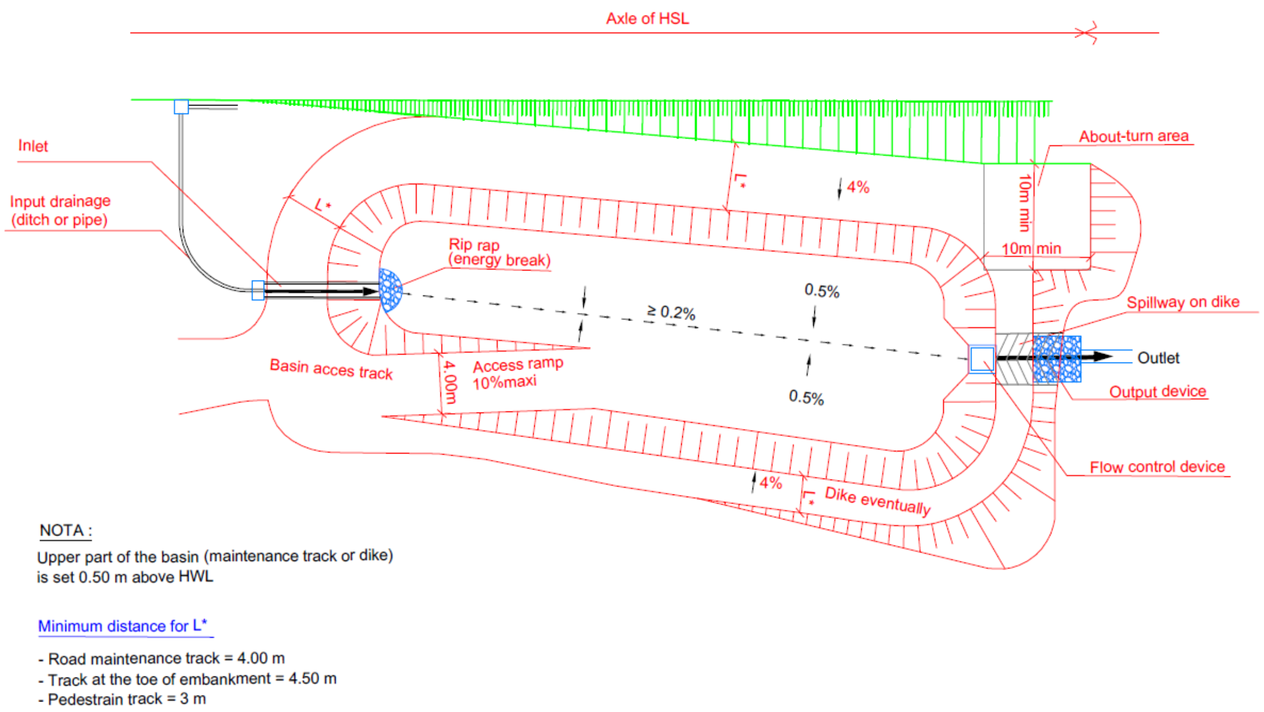

Figure 7. retention basin scheme

8.2.2. Installation

Basins shall be created wherever possible downstream of the line.

Basins located on the top of a railway cutting or embanked as well as basins whose highest level is above that of the high-speed line track bed elevation shall be subject to a risk assessment of the consequences of failure of basin and confirm that any such discharges do not affect HSL elsewhere. Risk assessment is based on special hydraulic and geotechnical studies.

Embanked basins located at the peak of cuttings are prohibited.

Basins enabling the infiltration of water must not in any circumstances endanger the stability of the infrastructure. They must be avoided in sectors at risk of cavities or liquefiable soils (cave-ins, gypsum, karsts, military land, etc...) and must be subject to a special study.

8.2.3. Sizing

The dimensions of the basins are calculated for 10, 50 or 100 years return period following the assimilation capacity of the natural body of water receiving flows.

For all basin, a risk analysis should evaluate the basin overflow points for events greater than the sizing return period. Depending on the risks for the track or the basin itself (flooding, erosion, etc.), additional facilities (ditches, rockfill, diffusing ditch, etc.) can be provided to protect infrastructures.

In natural environment, maximum water discharge is limited in accordance to local regulations.

In urban areas, criteria for discharge to public sewers shall be agreed with the sewerage undertaker as specific capacity constraints may exist at each connection point to the surface water or combined sewer system.

The design study for a retention basin shall in particular cover the following points:

- volume of the basin, which must take into account a freeboard of 0.50 m between the level of the highest nominal water and the top of basins,
- exfiltration mechanism,
- stability of the banks and/or of the dyke including the railway infrastructure and the geotechnical nature of the ground where it is installed,
- the hydrogeological context of the site,
- geometry of the basin: the form and installation of the basin must correspond to the necessary volume calculated (land regulation constraints must also be taken into account),
- Inlet pipe or ditch shall be above HWL of the basin,
- emergency spillway:

- this is compulsory where the basin is embanked or if the topography of the terrain is such that the situation is equivalent,
- this must be calculated for a centennial rainfall event,
- run-off must not be directed towards the new line,
- this may be combined with a diffusing ditch where the thalweg has no discharge channel,

- connection installations upstream and downstream, in order to enable their maintenance.

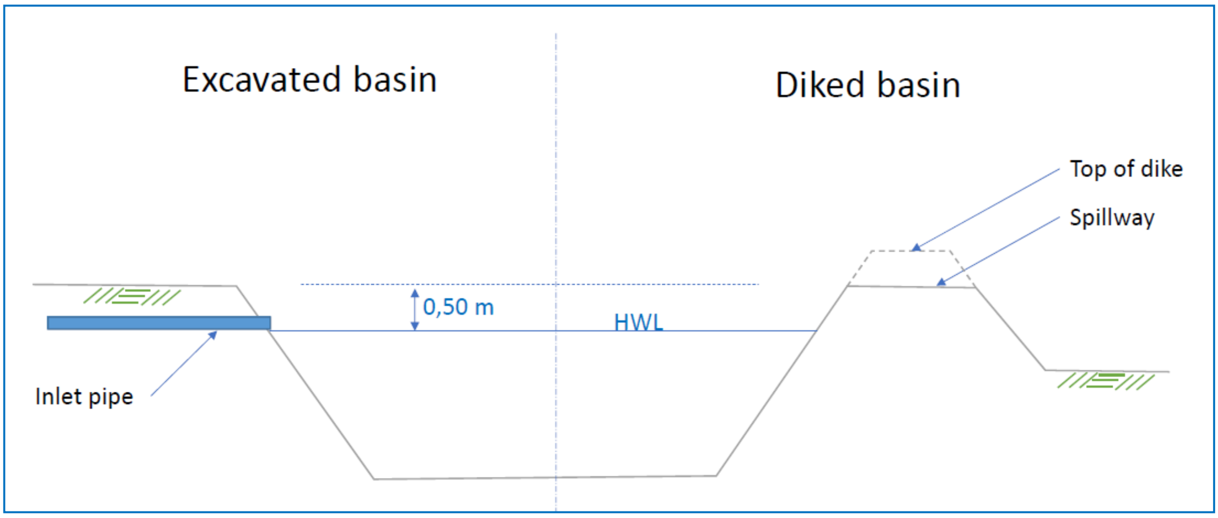

Figure 8. Relation of HWL in basin with inlet pipe and spillway

8.3. Storm water quality management

8.3.1. Description

Containment ponds are designed to intercept concomitant accidental pollution with intensiv rain. They are implanted at the ends of drainage networks before being discharged into the natural environment.

The basins are sealed to prevent pollutants infiltration to the natural environment.

Runoff from each rain event is detained and treated in the pool. The retention time promotes pollutant removal through sedimentation and the opportunity for biological uptake mechanism to reduce nutrient concentration.

Ponds can provide both storm water attenuation and treatment. For this, basin should respect both design criteria for retention of the outflow and for containment of accidental pollution.

The basins consist in:

- An inlet structure equipped with a shut-off valve to contain pollution during rainfall;
- Two volumes distributed in:

   - A dead volume set under the exit level of the basin. It serves to slow the spread of the pollutant through the basin and ensure an intervention time sufficient for emergency service;
   - A storage volume of the pollution and a low intensity rain. He is set above the dead volume;
- An output structure comprising a grid for retaining the main floating bodies, a siphon and a calibrated orifice for controlling the leakage flow;
- A bypass to isolate the basin in rainy weather as long as a pollution is confined into the basin.
- A safety spillway to evacuate flows in the event of rainfall exceeding the basin sizing period;
- A maintenance track around the basin and an access ramp to the bottom of the basin.
- A fence.

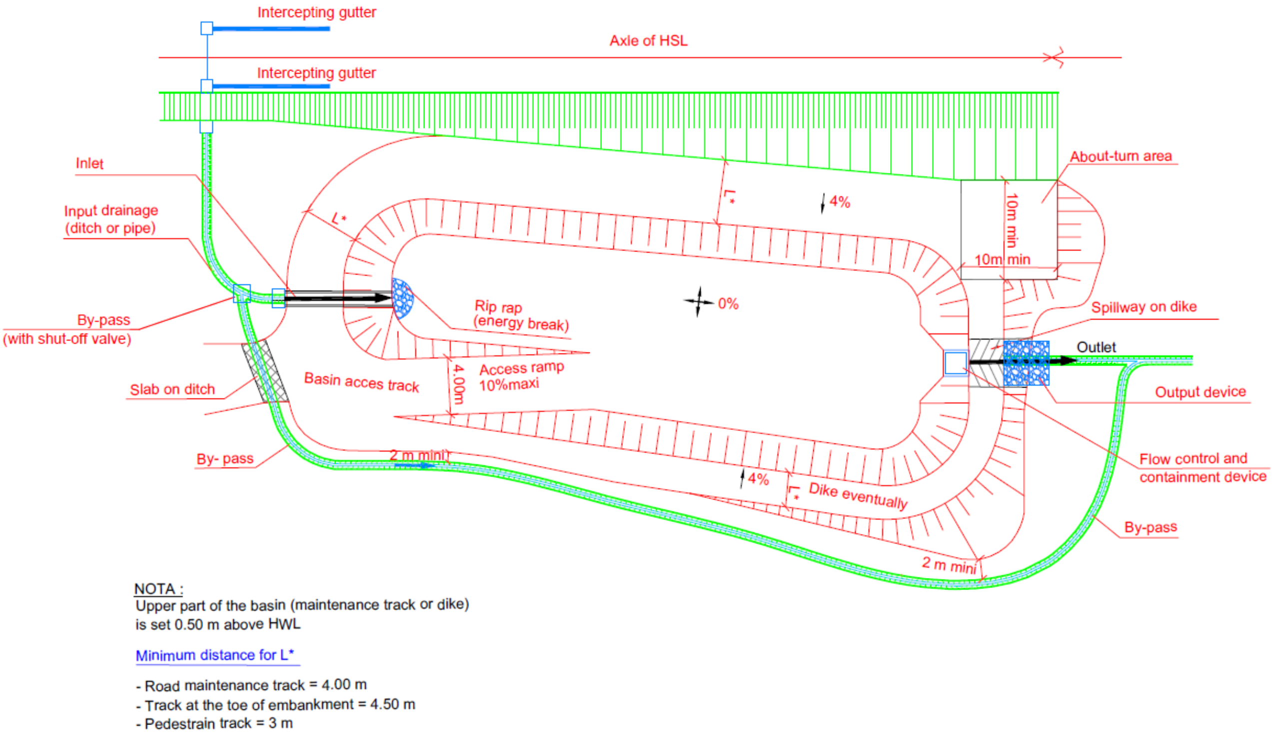

Figure 9. Containment and retention basin schema

8.3.2. Sizing

Containment volume and dead volume are calculated following local regulation.

In the absence of such regulation, the containment volume is calculated to contain the volume of water generated by a rainfall of 2 years return period and 2 hours duration, cumulated with the volume of the accidental pollution. It is determined from the following formula:

$$V_{Cont} = A_a \times D_{(T,d)} + V_{AP}$$

With: Vcont = containment volume

Aa = Active area

D(T,d) = rainwater depth for a return period T and duration d (m)

V_{AP} = volume of the accidental pollution

The intervention time is the time required in case of accidental pollution to close the shut-off valve of the basin. It corresponds to the time of distribution of the pollution through the basin. It is fixed with a minimum of **2 hours**.

The design study for a containment basin are the same than for retention basin.

In addition, the dead volume is set under the outlet pipe and have a minimum height of 60 cm.

The bottom of the basins is horizontal.

The bottom surface of the basin and its slopes are waterproofed to prevent the spread of pollution toward the groundwater. In the case of raising of the water table, a system should be carry out to prevent the risk of deformation of the sealing system due to Archimedes' buoyancy (draining layer, ballasting, pressure balancing vent, …).