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Environmental damage limitation from fire-fighting water run-off

Limitation des dommages environnementaux dus au ruissellement des eaux de lutte contre l'incendie

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Foreword

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In exceptional circumstances, when a technical committee has collected data of a different kind from that which is normally published as an International Standard ("state of the art", for example), it may decide by a simple majority vote of its participating members to publish a Technical Report. A Technical Report is entirely informative in nature and does not have to be reviewed until the data it provides are considered to be no longer valid or useful.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO/TR 26368 was prepared by Technical Committee ISO/TC 92, *Fire safety*, Subcommittee SC 3, *Fire threat to people and environment*.

Introduction

Fires involving commercial storage facilities and industrial plants are generally controlled by applying large volumes of water. These facilities routinely store or use large quantities of materials and manufactured products, often flammable and combustible. These substances, whether combusted or not, can be transported by uncontrolled water run-off in the event of a fire and could give rise to severe environmental pollution problems.

The latest Organisation for Economic Co-operation and Development (OECD) report in the series *Environmental Outlook for the Chemicals Industry*[1], notes that, in the European Union, chemical accidents that cause ecological harm often involve water pollution; this pollution is frequently the result of fire-water run-off.

The seriousness of these threats depends on various factors, including the nature and quantity of the materials involved, the emergency planning measures in place, and the location of the fire relative to susceptible populations and environments. Contamination far beyond the locality of the fire can result from fire scenarios that generate large quantities of harmful combustion products and fire suppression that involves large quantities of water. The environmental hazard can be worsened by interactions between the product that is burning, the combustion products produced and the extinguishing agent.

This Technical Report provides a summary of current approaches to controlling and reducing adverse environmental impacts caused by fire-water run-off. The intended audience for this Technical Report includes, but is not necessarily limited to:

— Fire-fighters and investigators.

— Building owners and managers.

— Storage facility operators.

— Materials and product manufacturers.

— Insurance providers.

— Environmental regulatory authorities.

— Civil defence organizations.

— Public health authorities.

— Industrial safety authorities.

Environmental damage limitation from fire-fighting water run-off

1 Scope

This Technical Report provides information for the development of specifications and procedures aimed at limiting adverse environmental impacts caused by fire-water run-off (see References [2] to [7]). The information is applicable to commercial facilities, such as warehouses, chemical storage facilities, refineries, process plants which handle and/or store products with a potential pollution potency, and vehicles for the transport of such substances. It is only applicable to land-based operations (i.e. not oil tankers or off-shore oil drilling platforms), and to wildland fires.

As such, this Technical Report provides a summary of current potential approaches for controlling and eliminating adverse environmental impacts caused by fire-fighting water run-off. It offers relevant information for the design and sizing of water basins to limit the dispersion of contaminated water into the environment at large (see References [8] to [12]). This Technical Report is divided into three main parts: a description of the hazards of fire run-off, environmental damage limitation and details concerning the possible design of water basins.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 13943, *Fire safety — Vocabulary*

ISO 14001, *Environmental management systems — Requirements with guidance for use*

ISO 14050, *Environmental management — Vocabulary*

ISO 26367-1, *Guidelines for assessing the adverse environmental impact of fire effluents — Part 1: General*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 13943, ISO 14001, ISO 14050, ISO 26367-1 and the following apply.

3.1
fire effluent
totality of gases and aerosols, including suspended particles, created by combustion or pyrolysis in a fire

NOTE For the purpose of this Technical Report, fire effluent also includes run-off water generated during fire-fighting activities.

3.2
fire-water run-off
aqueous fire effluent containing dissolved and waterborne materials

NOTE Materials that may be present include substances affected by the fire, combustion products, and substances used to fight the fire.

3.3
biochemical oxygen demand
BOD
indirect measure of the concentration of biologically degradable material present in water

NOTE This definition is based on OECD documents (References [13] and [14]).

3.4
chemical oxygen demand
COD
measure of the oxygen required to fully oxidize all compounds, both organic and inorganic, in water

NOTE This definition is based on OECD documents (References [13] and [14]).

3.5
contaminated fire water
water that has become contaminated with process materials used at a facility and the products resulting from combustion or products used as part of the extinguishing process

4 Emission to the aquatic environment

4.1 Contamination pathways

4.1.1 General

The major threat to the aquatic environment posed by fires arises from the direct run-off of contaminated fire-fighting water into rivers, streams, lakes, ground waters and sewage treatment works.

The polluting effects of fire-fighting water run-off, related to both surface water and ground water, are due to one or more of the following:

— direct toxicity or ecotoxicity (i.e. LD_{50} determination on Daphnias);

— an increase or decrease in the biochemical oxygen demand (BOD);

— an increase or decrease in the chemical oxygen demand (COD);

— physical effects such as suspended solids polluting river beds or the gills of fish;

— sanitary quality of public bathing water;

— an increase or decrease in pH;

— metals released in the environment.

4.1.2 Impact modes

The impact that any discharge of fire run-off has on the aquatic environment is determined by a wide variety of factors:

a) The volume of run-off produced, the time of travel from the site of the fire to the receptor, the dilution afforded in the receiving water body, and the temperature and chemistry of the receiving water body.

b) The sensitivity and the distance (time of travel from the site) of the primary and secondary receptors, such as public drinking-water abstraction points, fisheries and all potential aquatic and non-aquatic ecosystems.

c) The chemical composition of the run-off as determined by the source of the fire, e.g. in the case of fires at sites storing chemicals, a complex mix will be involved including:

   — the stored chemicals and their thermal decomposition products washed off the site by the run-off,

   — the solid and condensed decomposition products of combustion of the building and of substances stored on site, and

   — additives to the water used in fire suppression, such as fire-fighting foam.

NOTE 1 Contamination could be a consequence of interactions between the pollutants and their targets. For example, pollutants can be concentrated at different steps in a food chain and their impact can occur far from the primary affected targets.

NOTE 2 References [15] to [20] give information on the toxicity of chemical fire suppressants.

Contamination can be in the form of pollutants floating on water, pollutants miscible in water, and pollutants mixing with sediment.

4.1.3 Acute effects

The acute effects of a discharge of run-off to surface water usually appear immediately. The impacts, although often short term, can be very serious and can include the contamination of public drinking water supplies during or immediately following the fire. The effects are usually greatest within the immediate vicinity of the site, where the levels of pollutants will be at their highest. Acute effects can be followed by long-term disruption in the ecosystem that can occur up to several years after the contamination event (see A.4).

NOTE Acute effects can also peak at some distance from the fire. For example, an oxygen sag can form downstream of the discharge point when more toxic breakdown products can be formed, such as ammonia forming from the breakdown of protein-based foams. Furthermore, sensitive receptors can be located well downstream of the discharge point.

4.1.4 Long-term effects

Long-term environmental impacts from exposures to large fires (i.e. the impacts occurring after the fire, over a period of years) will be experienced largely within the local environment, within the fire deposition zone and along impacted streams and watercourses and ground waters as defined in ISO 26367-1. Information concerning such incidents can be found, for example, in the Major Accident Reporting System (MARS) described in the Note below.

NOTE The Major Accident Reporting System (MARS) is a distributed information network consisting of 15 local databases on an MS-Windows platform in each Member State of the European Union and a central UNIX-based analysis system at the European Commission’s Joint Research Centre in Ispra (MAHB, Major Accident Hazards Bureau) that allows complex text retrieval and pattern analysis. MARS is used by both EU and OECD member countries to report industrial accidents in the MARS standard format and to exchange accident information (see Annex A).

Long-term impacts can also arise from direct ingestion by flora and fauna of toxic/carcinogenic/ecotoxic organic compounds within watercourses contaminated by fire-water run-off. Pollution of ground water can also lead to the long-term (decades) or permanent closure of public and commercial water supplies that are drawn from ground water or taken from surface waters that are fed by contaminated ground waters.

The nature and place of any intervention that occurs has a major effect on the environmental impact of that intervention. Some information is given below concerning what is appropriate to monitor in order to determine the environmental impact of a particular intervention and whether a controlled burn (i.e. allowing a fire to burn out under the control of the fire authorities) is not sometimes a viable alternative to traditional extinguishment. If extinguishing media have been collected, samples should be taken for analysis. Further, samples should also be taken from ground water and surrounding watercourses or lakes.

The exact species that should be monitored in samples taken on site should be determined based on the products stored on site and their likely breakdown products as well as on the fire-fighting agent(s) used. Examples of relevant analyses include: PAH, dioxins, metals, pH, BOD, COD and suspended solids (SS). In some cases, toxicity tests and biological monitoring may also be useful.

In cases where action is required to prevent the fire from spreading, for example by applying cooling water to the area around storage tanks, care should be taken to ensure this water does not become polluted.

4.2 Control of fire-fighting water run-off to surface water and ground water

Fire-fighting water containment should be considered for industrial sites over and above the requirements for ordinary bundings and secondary containment systems. A containment system may be needed to protect both surface and waste-water drainage systems. Lagoons may be constructed whose retention capacity is adequate for the area concerned. Specific places, such as car parks, should be identified as potential capture areas as these are easily modified to provide retention capacity for run-off water.

4.3 Permanent or portable tanks are another option for fire-water retention

Permanent or portable tanks should be constructed of a material resistant to the substances intended to be retained and tanks should be vented to avoid pressure build-up. Shut-off valves or penstocks that can isolate parts of the site in an emergency are another alternative to prevent contaminated water from reaching a drain or surface water. In this case, the contaminated water is held within the drainage system and removed as soon as practicable (and with the approval of the environment gency and/or sewerage provider). Further information on the types of system that can be used can be found in References [10], [21] and [33].

5 Environmental damage limitation

5.1 Initial risk assessment

Identification of pollution sources, assessment of the risk and development of protection strategies should be defined and developed prior to a major incident. The protection strategies identified should take into account possible atmospheric pollution, domino effects, water run-off displacement, which samples should be taken and which analyses should be conducted.

5.2 Risk reduction strategies

If the risk screening assessment shows a high or medium risk of pollution from fire-fighting, site operators, in liaison with fire and rescue services, environmental regulators and other stakeholders, should consider ways to reduce this risk to an acceptable level or mitigate the impact of the risk.

There are four main ways to reduce risk, which can be implemented at any given site:

a) Prevention

   This measure should be given the highest priority, i.e. the prevention of the fire in the first place, e.g. by segregating or controlling sources of ignition.

b) Automatic detection and fire protection

   This measure ensures that if a fire does start, it is detected and fire-fighting is instigated as quickly as possible. The fitting of automatic detection and protection systems such as automatic sprinkler systems is one traditional methodology although numerous others exist. Site operators should seek advice on such systems from fire experts, such as the Fire and Rescue Service and their insurers.

c) Containment

   This measure mitigates the impact of a fire through the installation of facilities for containing fire-water run-off such as storage lagoons or chambers, shut-off valves and isolation tanks or areas.

d) Alternative strategies

   This measure reduces the impact of a fire by planning suitable fire-fighting strategies with the Fire and Rescue Service, such as:

   — reducing the amount of fire water generated, such as by using sprays rather than jets;

   — recycling fire water where this is not hazardous.

5.3 Fire-fighting tactics

5.3.1 Relation between fire-fighting tactics and water usage

Fire-fighting tactics have a strong impact on the nature and volume of fire-water run-off. There are two main strategies for fire-fighting tactics in industrial fires within the scope of this Technical Report. The choice between the two different tactics depends mainly on the nature of the fuel involved. The main steps in both tactics are listed below:

a) **Limitation of the propagation of the fire**. Fire-fighting is related to the limitation of the fire propagation to a given limit determined generally by fire-fighters as part of the strategic planning for an industrial site. The goal of this first step is to avoid propagation to surroundings, e.g. other buildings. At this step, the extinguishment medium is typically water.

b) **Fire control**. In this case, propagation is limited and the progress of the fire towards extinguishment has started. This part of the operation can begin within a few minutes to hours after starting the fire-fighting. Depending on the nature of the fuel, tactics will differ in this step, e.g.:

   1) *Hydrocarbon fires (refineries and oil depots, gas stations, rail and road tanks), chemical industries and some warehouses*: In this case, foam is required in order to proceed to extinction. Tactics involving foam need significant hydraulic systems and lead time before applying the extinguishing medium. During this delay, fire is limited (“controlled”) by water.

   2) *All other fires*: In this case, water is used in variable quantities to bring the fire to extinguishment, depending on the specific fire to be controlled.

c) **Fire extinguishment**. This is the final step, which is also coupled with a survey of the damage and plan for the next steps (i.e. fire survey).

In step 5.3.1 b), when foam is used, extinguishment will usually be quick (a few minutes) once the foam application has begun. If not, there is a risk that the fire will reignite and the procedure must be restarted. Tactics using foam are typically considered to require at least double the time of other tactics. This generates a much greater volume of water, and the presence of foam and emulsifier agents leads to a more complex composition of the water to be managed both in terms of quantity and toxicity.

5.3.2 Controlled burn

In some very specific cases, the fire-fighting tactics can specifically involve a decision to “not attack the fire actively”[22][23] in the fire-fighting operations once the risk of escalation has been minimized and there are no further risks to humans. This is often called a “controlled burn” tactic. This is generally chosen for one of three main reasons, i.e. when fire-fighters do not know how to extinguish the fire, when the risks associated with active fire-fighting are too great for the fire-fighters, and upon directive from the relevant jurisdiction authority. The choice to use this approach may minimize adverse environmental impacts caused by polluted fire-water run-off by restricting the use of fire-fighting media such as water or foam. Under some circumstances, these tactics may also reduce air pollution as a consequence of more efficient combustion and dispersion of gaseous pollutants formed in the fire. This tactic may be used as the sole fire-fighting strategy or as part of a strategy when water/foam are also used during different stages of the fire. The choice of this tactic, however, involves complex decision making by the fire management team. In this contex, it is important to consider:

— What effect fighting the fire with water or foam may have in terms of potentially contaminating water resources, fisheries, aquatic fauna and flora.

— Whether there is a realistic possibility of managing a controlled burn, without attempting extinguishment, taking into account the accompanying risks of short-term air pollution and longer-term pollution of land and water in the event that the smoke plume comes to ground level, and the risk of fire spread to adjacent structures.

— Whether it is possible to minimize adverse health effects on humans (as this takes priority over environmental concerns).

5.4 Factors in assessing the volume of water run-off

5.4.1 Process facilities

To assess the volume of contaminated fire water that may be generated in the process areas, the following points should be considered:

a) The construction of the main sprinkler distribution pipes (150 mm or above) and level of explosion proofing according to ISO 6182-1[61]. Rules to design sprinkler explosion resistance can be assessed by existing engineering guidance[24][25].

b) The Assumed Maximum Area of Operation (AMAO) on which the sprinkler design is based compared to the actual floor area.

c) The presence of compartmentalization and the level of fire resistance supporting such compartmentalization (e.g. fire doors, etc.).

d) The presence of explosion-relieving areas and walls in the building design.

e) The volume of process water/product present in the process equipment that may combine with and contaminate the fire water.

f) The volume needed for rain/standing water in the process.

5.4.2 Tank farm zones

To assess the volume of contaminated fire water that may be generated in the tank farms, the following points should be considered:

a) The design and duration of the deluge system.

b) The number of tanks, their size, construction or separation distances[26].

c) The presence of radiation walls.

d) The size and make of bunds.

e) The type and quantity of product at risk.

f) The location of the tank farm and its proximity to other property.

g) The volume needed for rain/standing water in the process.

Potentially environmentally damaging materials should always be stored in adequately bunded areas. Bunds are normally arranged to hold the total of the tank volume, plus 10 %, this being the volume of the initial fire-fighting or fire protection water or foam. However, much more than this volume would be required to fight a fire. Therefore, bunds cannot normally be relied on as fire-water retention. They should only realistically be used to provide temporary containment to gain time.

5.4.3 Warehouse zones

To assess the volume of contaminated fire water that may be generated in warehouses[27][28][29], the following points should be considered:

a) The sprinkler design density and duration at the roof level, and whether in-rack protection is included.

b) The nature of the materials stored.

c) The warehouse design.

NOTE The emergency plan may consider fire-fighting strategies and possible ways to reduce the amount of fire-water run-off generated. For example, this could be by the use of sprays rather than jets, allowing controlled burning and possibly recycling of fire-fighting water where it is safe to do so.

6 Rules to design water basins

6.1 Characteristics to design the water basins

Water basins are defined by three main characteristics: size, construction, and location. The level of risk one is willing to assume applies to all three. Thus, one might assume a given level of risk by sizing the basin for an above-average fire, rather than a maximum fire. Based on another risk assessment, one might choose not to line the basin, allowing some rare solutes to leak into the soil. Further, again depending on the risk, one might locate the basin so that not all the run-off water reaches it.

6.1.1 Risk classification

The risk classification and hazard category affect the containment design. These parameters are often used as input data in water basin design methods. The risk quoted depends on fire causes (e.g. process default affecting valves, pipelines and tanks, etc.). The initial risk analysis has to be evaluated regarding the potential impact on the environment from water run-off as the safety objective. It is also important to note the possible polluting effects of a mixture of materials (including physical or chemical modifications) that may arise during a fire. Environmental risk assessment can be evaluated using a fire safety engineering approach (see ISO 16732-1[62]).

Another aspect to consider when determining the risk classification is the location of the water basin. The distance between the possible fire area and the potential retention basin is an important parameter. It is necessary to have a short distance between the water basin and the fire. The water run-off pathway should be reduced or designed to limit leaks on the way to the retention basin. Further, the intensity of fire expected will impact on the positioning of the basin. Damage to the water basin from the fire should be limited to avoid compromising its retention capacity, i.e. the basin should be accessible during the fire if needed, but not so close as to risk damage.

Risk classification in the design of water basins is an ambiguous parameter. Poor application of this parameter can lead to a reduction in the capacity of the water basin because of the occurrence probability of fires. Therefore, the risk classification should be considered carefully in establishing the seriousness of any given event. In this context, the fire occurrence should be considered as deterministic.

6.1.2 Hazard category of substance

The quantity and nature of hazardous materials present is clearly an important factor. This should be taken into account when determining the containment capacity. The quantity and nature of the materials present has a direct impact on the fire growth, the difficulty to control or extinguish the fire, the compatibility with various extinguishing agents, etc.

There are different hazard categories of substances in various methods used to design water basins. The potential pollutants are classified according to a range of raw materials, products, fuels, wastes, etc. Their intrinsic properties (chemical, physical), their potential environmental impact (biochemical, ecotoxicological, etc.) and the quantity of these materials should also be taken into consideration. Hazard categories of a wide range of substances may be found in different industrial methods or on the basis of European regulations (see References [30] to [40]).

Depending on the prevention and protection measures considered, some methods suggest that the hazard category proposed for a substance should be reduced in some way. Such measures include:

— Limitation of stored quantities.

— Prevention rules.

— Protection devices (detection, automatic extinction, fire-fighting proximity and equipment).

6.1.3 Possible fire area and fire duration

The design of a water basin is tied to fire intensity, in terms of size and duration. Some information concerning material nature, quantity stored, storage configuration, meteorological conditions (e.g. wind, rain) is needed to predict the fire area as a function of time and fire duration. Analytical or numerical models can be used to determine the fire scenario in terms of fire size, heat released and temporal history. These models consider several hypotheses and databases issued from literature, such as burning rates and heats of combustion.

The use of such models can be very sensitive to input data or model capabilities and should be applied with care. In addition, data issued from statistics on similar fire size and duration can be useful for deterministic risk classification.

6.2 Common characteristics of water basins

6.2.1 Common safety characteristics

To protect surface water and ground water, common safety characteristics include:

— Protection against loss of primary containment using high-integrity systems. These include distance between fire and basin, leaks during water run-off pathway to the basin and containment leaks. To reduce the loss of water run-off, some modifications such as impermeable liners are often used.

— Necessity to install retention basin with appropriated dimension, tightness and intermediate technology.

— Knowledge of position of chemical products, and selection of proper placement of basins installed.

6.2.2 Classification of water basins

Water basins can be classified in a few categories according to their base design and collection method:

— Those built directly inside or under the protected installation to retain contaminated fire water in the self-working systems, such as in tank storages built in their own basin.

— Those built close to the protected installation. These systems should be triggered directly and automatically by gravity or should be manually operated.

— Those placed in case of fire or defined by a variable capacity storage (mobile systems).

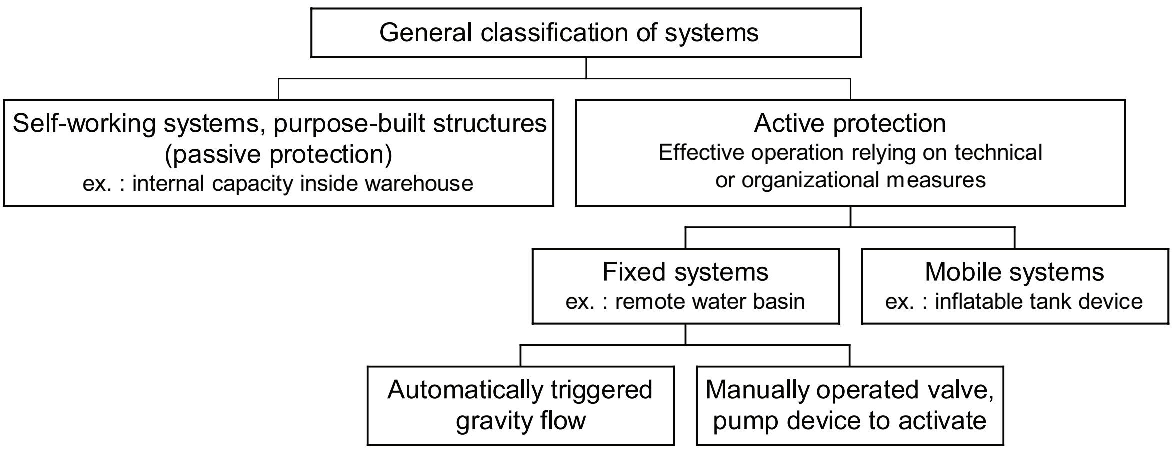


Figure 1 — General classification of water basin systems

6.3 Methods to define water basin capacity

6.3.1 Maximum required retention volume for fire-water run-off

The following quantities should be determined as a basis for calculation of the maximum required retention volume for fire-water run-off:

a) The total volume of water likely to be used to fight the fire. Methods suitable to determine this volume are presented in the following paragraphs.

b) The volume of contaminated water to be retained for each of the main site areas.

c) The expected total volume of contaminated fire water based on the largest volume calculated for each of the main site areas.

d) The expected volume of rainfall, based on maximum level of water retention under normal usage conditions.

e) The total required retention volume for contaminated fire water.

The largest volume calculated for process areas, tank farms and warehouses is selected as the initial estimate of the volume of contaminated fire water. This estimate is then compared with the fire water likely to be used for the site. The larger volume is selected as the required retention volume for contaminated fire water.

Provision for the retention of rainwater that occurs prior to or during the fire must also be included in the estimated retention volume required. The actual volume of rainwater to be retained should be determined on a case-by-case basis fed by meteorological databases. In general, the area of coverage should comprise the total plant area.

Different methods to define water basins and their main characteristics are presented in Annex B.

6.3.2 Size definition by “magic numbers”

The size definition by “magic numbers” is a deterministic approach based on feedback from specific accidents. Many industries developed such methods after the Sandoz fire (see A.4 and References [46] to [51]). These methods are mainly based on tabulated values. In general, the volume of the water basin is defined as ranging from 3 m^3 to 5 m^3 per ton of material stored. The volume is defined based on the:

— Stored quantity of combustible materials, to define size of compartment.

— Hazard categories of stored products.

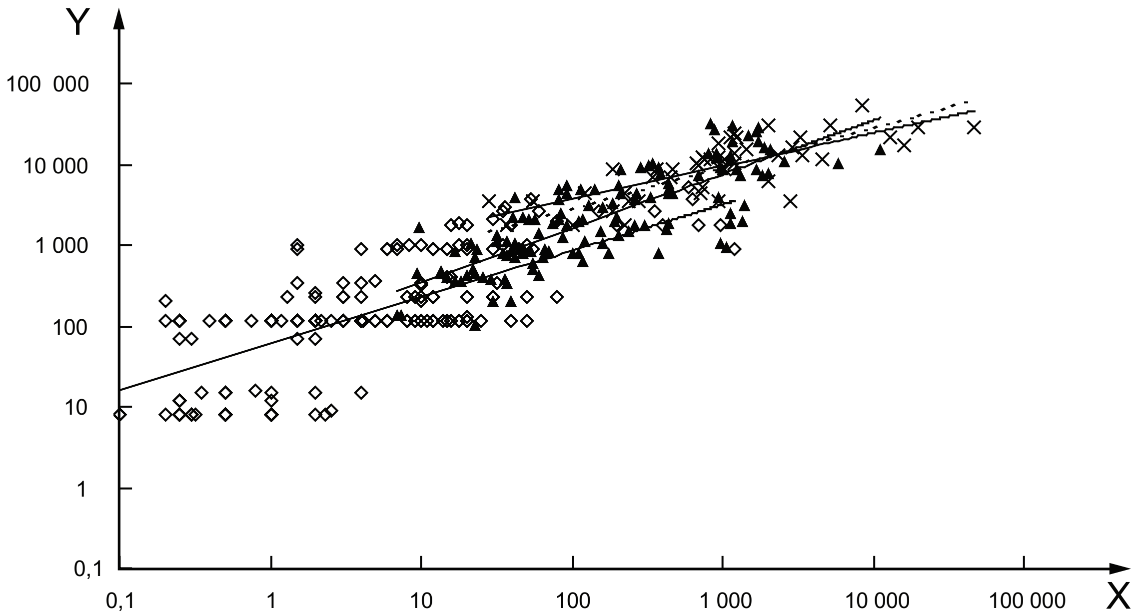
— Expected fire duration.

This kind of method is simple to apply, with little input data needed. Nevertheless, “magic numbers” are issued based on only a few case studies and are difficult to extend to every potential fire scenario.

6.3.3 Size definition by model curves

Various authors (Thomas 1959, Baldwin 1972, Särdqvist 2000[40]) statistically analysed water flow rates needed by fire and rescue services to extinguish fires versus fire area, for small and large fires. They found bi-logarithmic relationships between these parameters, with an important variability (see Figure 2). These data complemented by fire duration can be useful to define common rules for water quantity needed to extinguish fire, and therefore to define water basin capacity. Statistical data on the time needed to control fire were also established (see Figure 3).

These analyses have advantages given the large number of fires considered. The total water quantity used, and thus the size of water basin, is the product of the water flow rate by the control time. Nevertheless, detailed analysis shows that there is an important variability in the water flow rate needed to extinguish any given fire.



Key

X fire area (m²)

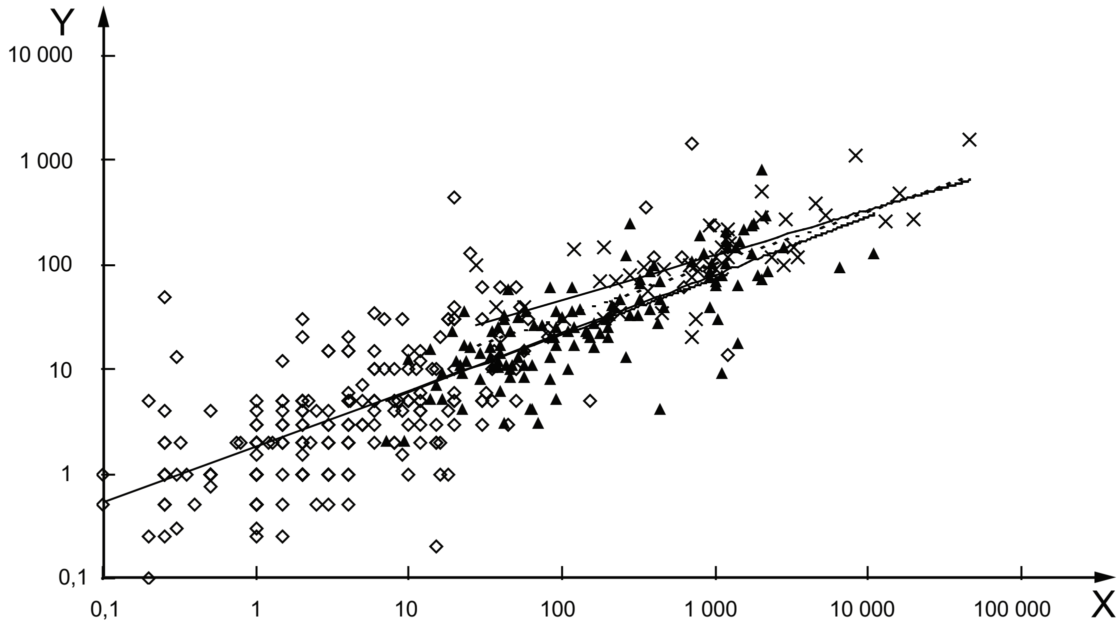
Y water flow rate (l/min)

× Thomas - 59

▲ Baldwin - 72

◇ Särdqvist - 00

Figure 2 — Data and correlations from different investigations on the use of water by fire brigade



Key

X fire area (m^2)

Y control time (min)

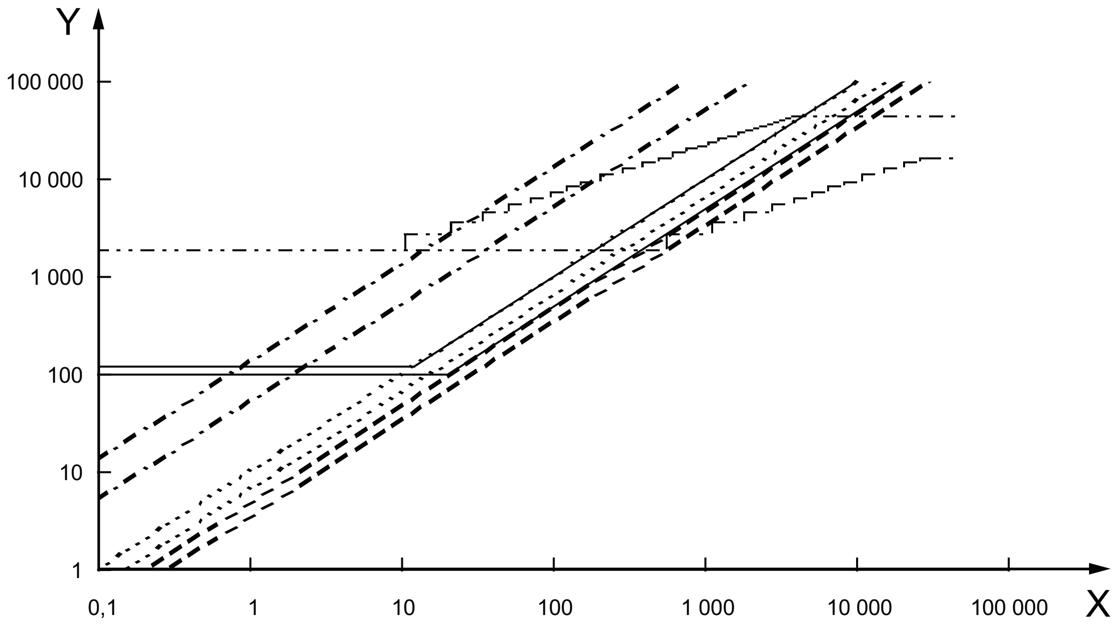
× Thomas - 59

▲ Baldwin - 72

◇ Särdqvist - 00

Figure 3 — Data and correlations on time taken by fire brigade to control fire

All these statistics have been used to construct conventional curves defining the relationship between fire area and water flow rate. The curves developed by various authors are presented in Figure 4. They all have an upper and lower curve.



Key

X fire area (m²)

Y water flow rate (l/min)

_ · · _ · Insurance Services Office

_ · _ · _ Buchanan

______ Sprinkler

. . . . Firepro

_ _ _ _ Royer

Figure 4 — Curves of water flow rate vs. area in fire[40]

Regarding statistical data and the above curves, it appears that they often define the lowest rates rather than what would realistically be expected to be produced by real fires. Moreover, models used to define these curves are based on various hypotheses and approximations of the area of the fire and what is burning. There is a lack of knowledge concerning the definition of these curves, which could limit their utility.

6.3.4 Size definition by risk-based approach

A risk-based approach may be used to assess the pertinence of an existing capacity to retain contaminated fire water for given premises or to determine the size of a new capacity for industrial facilities which do not have existing means of retention. This methodology leads to the design of water systems based on hazard analysis and quantified risk assessment. One possible flowchart to deploy such a method is given in Reference [41] and Annex C. In general, such a method goes beyond the simple sizing of a water basin, as it is a global method of risk management assuming a potential release of hazardous materials in receiving waters from an industrial site.

The main steps are as follows:

— Identification of hazardous materials that can contaminate waters.

— Identification of mechanisms of release (needs determination of typical accident scenarios).

— Evaluation of sensitivity of aqueous ecosystem (nearby rivers and lakes, ground water, etc.) according to nature and quantity of pollutants received and characteristics of local fauna and flora.

— Estimation of potential volume of contaminated water as well as concentration and loading of pollutants, including impacts of local rainfalls and volumes of fire-fighting waters from the range of pertinent fire scenarios. In parallel, this step requires the estimation of material leakage and spillage volumes, according to given accident scenarios.

— Consequence analysis of accidental discharge of water pollutants according to previously obtained data. This is a complex step as it requires the consideration of many variables including:

  — physical dispersion of pollutants,

  — degradation of materials,

  — concentrations reached in the receiving waters,

  — duration of the pollution event (and concentrations of concern in receiving waters),

  — short-, medium- and long-term impact of the contamination on the species of the ecosystem.

The water quality criteria that exist in many countries may be useful for this complex step. This part of the process may lead to the conclusion that no water basin is required. If, however, the conclusion is that consequences are not acceptable, a further process leads to the sizing of a retention capacity.

The effective sizing step, in addition to taking into account all previous data, will proceed to a frequency/probability analysis obtained by a comprehensive fire safety study comprising: frequency and magnitude of rain events, frequency of fires and quantity of water to be applied. From a probabilistic point of view, the final sizing may be the result of an iterative process based on an acceptance criterion in terms of frequency of discharge of contaminated waters off site. The probability that the contaminated water volume will exceed the capacity of the water basin under consideration can be expressed as a function of the size of the retention capacity.

6.3.5 Moderation factors

Protective measures such as sprinklers or material limitations can be used in the design of the installation. For some water basin design methods, the volume of the water basin may be reduced if protective measures have been taken that can control the fire to a limited area. Nevertheless, if devices like sprinklers are used to control fire, their water release has to be considered in the final design of the water basin.

Special attention has to be given to the maintenance of active protection devices and their efficiency when their usage results in a reduction of water basin volume.

Annex A
(informative)

Example case histories

A.1 Buncefield Supply Depot

Buncefield, UK, December 2005[42][43].

Following the Buncefield Depot fire, approximately 23 million litres of contaminated fire water were successfully contained. However, the post-fire issue of how to deal with this contaminated run-off has caused as many problems as extinguishing the fire itself. It should be recognized that this volume of contaminated fire-water run-off did not reach sensitive water systems, in stark contrast to previous cases. Containment in this instance was the first and most important priority, given that the degradation products from the foams used during this fire were expected to contain both PFOS1) and H-PFOS2). The problem in this case was not just the volume of water but the level and types of contamination contained in the water. It is not credible to simply hope that a water company can mix these waters with those that are normally treated, such as sewage. It is necessary to define a plan for orderly treatment and destruction of such contaminated fire-water run-off, which was done by the UK EPA.

The contaminants present in this fire-water run-off are likely to destroy vital biosystems used to biodegrade sewage during treatment. Furthermore, the fluorinated materials found in the foams used during the fire will not be removed by water purification processes and will remain and build-up in the retained sludge, which is then normally sent to agricultural land. The only safe option for dealing with fire-water run-off of this type is to systematically employ processes that remove the individual contaminants such as hydrocarbons, oils, grease, polyaromatic hydrocarbons, proteins, etc. The fluorinated species can then be removed by filtering the water through a specially designed carbon matrix.

Simply diluting fire water does not remove contamination. The contamination remains, regardless of the amount of dilution. As a case study, the Buncefield incident has not yet reached a conclusion. However, the clean-up operation will have implications for the fire engineering industry long into the future.

A.2 Abidjan Supply Depot

Abidjan, Ivory Coast, May 1999[44].

During the fuel supply depot fire in Abidjan, Ivory Coast, May 1999, approximately 245 000 l of emulsifier were used to extinguish a car gas tank of 30 000 m^3. A large fraction of the water used came directly from a sea lagoon, close to the depot. The fire burned for six days. During this time it was under control several times, but restarted twice.

The tank basin level was limited to 3 m in order to avoid overflow. Almost all foam produced was released to the environment.

A.3 Saint-Ouen Supply Depot

Saint-Ouen, France, 14 June 1991[45].

During the fuel supply depot fire in Saint-Ouen, France, June 1991, approximately 3 million litres of water and 42 000 l of emulsifier were used to extinguish a fire of 620 m^3 of automotive gasoline and 50 m^3 of diesel

1) PFOS: perfluorooctane sulfonate, fluorinated surfactant used formerly for fire-fighting foams.

2) H-PFOS: In the H-PFOS molecule commonly described as 6:2 FtS or fluorotelomer sulphonate, six of the eight carbon atoms of PFOS are fluorinated. This molecule could be produced in fires by degradation of PFOS.

oil. The fire duration was eight hours from ignition to extinguishment. The fire was external to the fuel tanks, and was fed by an open fuel valve. The continuous arrival of fuel by this valve contributed to the continuous destruction of foam, immediately after application.

The quantity of automotive gasoline released into the environment is considered significant, and very little water was retained and treated, leading to pollution of the Seine river. At the date of the fire, it was classified as being without consequences to the environment according to the SEVESO directive classification criteria. The consequences of the disaster on the environment were greatly underestimated.

A.4 Sandoz Chemical Company

Basle, Switzerland, 12:30 AM, 1 November 1986[46][47][48][49][50][51].

The Sandoz chemical warehouse fire constituted a blaze at a chemical storage warehouse. Large volumes of water were used to fight the blaze (400 l/s of water over a period of hours), and much of this water flowed back into the Rhine River. Although the fire-water run-off only took place for several hours, the cocktail of biocides and other toxic chemicals killed all aquatic life near the site and extended many miles downstream. Eels were found dead up to 200 km downstream of the incident site, and lasting effects to aquatic life were evident for years following the incident. The warehouse contained 1 351 t of chemicals, 987 of which were agrichemicals including the highly toxic organophosphate insecticide Endosulfan, Tetradifon, compounds of mercury including phenyl mercury acetate, phosphoric acid esters, and rhodamine pigment. Large amounts of mercurical compounds in the fire-water run-off posed extreme toxicity to the fish life in the river. Another factor in this incident was the toxicological contribution of secondary reaction products during combustion.

The Sandoz ecological disaster was primarily a function of poor facility placement and a lack of emergency planning. The storage facility for large volumes of ecologically hazardous chemicals was placed in close proximity to a major river waterway. Chemicals with incompatible characteristics (e.g. oxidizers and flammables) were stored in close proximity in the same facility. The turnover of materials was very high. Sprinkler systems were inadequate, and no bunds or other means to physically control run-off were present.

A.5 Allied Colloids Chemical Company

South Bradford, UK, 21 July 1992[52][53].

The Allied Colloids warehouse, based in South Bradford, was the main production site for this company. A fire broke out due to the presence of strong oxidizers located near raw materials. Four million gallons (about 16 million litres) of water were used by fire-fighters over a 3 h period to extinguish the fire. During this period, materials stored in the warehouse reacted with water to form viscous polymers. These subsequently blocked site drains and pumping systems, thereby preventing adequate drainage of the fire-water run-off and causing it to spill into nearby river waterways around several manufacturing areas. Ecological effects of this spillage resulted in fish being killed up to 30 miles downstream of the incident.

The situation was further worsened by the fact that the warehouse did not have a sprinkler system in place at the time of the fire. Post-fire improvements aimed to retain and control any future fire-water run-off include: a water supply, drainage, and water retention system. A reservoir (27 m $\times$ 27 m $\times$ 7 m) capable of holding 4 million litres of water for fire-fighting purposes, was built by the company and this can be topped up at the rate of 8 000 l/m (the cost of this was 0,5 million pounds in 1992). A ring main water supply has been installed throughout the site, with hydrants at appropriate points. An effluent retention basin was also constructed, which holds up to 8 million litres in several compartments linked by pumps. The retention basin serves to collect storm-water run-off as well as fire-water run-off. This enables water, which may be either transferred to a treatment system or directly into the sewer, to be tested.

A.6 Plastimet

Hamilton, Ontario, Canada, 9-12 July 1997[54].

This facility contained large amounts of solid polyvinylchloride (PVC), amounting to about 400 t, which were consumed in the blaze lasting several days. Run-off from the fire water entered surface waters and nearby land areas. People located nearby the fire reported symptoms of eye, skin and throat irritations, which were most likely caused by exposure to high concentrations of hydrochloric acid (HCl) released from the combustion of the PVC, but may have also been from high levels of organic irritants formed from combustion, such as acrolein. In addition to the HCl released by the burning of PVC, a number of toxic chemicals were released, including benzene, chlorinated dioxins/furans (“dioxins”), polyaromatic hydrocarbons, and metals. Local authorities used ambient air and water quality criteria to assess the magnitude of environmental risks from the fire and run-off. No biological surveys were available describing the extent of any ecological impacts of this event.

A.7 Tyre fires

Details on tyre fires can be found in References [55] to [60]. A worked-out limestone quarry used as a dump for 15,000 t of used tires and unknown amounts of chemical waste was the scene of a large fire in April 1978. Attempts to fight the fire produced a large volume of toxic, oily water which escaped into nearby streams, where complete elimination of aquatic life resulted. Concentrations of phenols and cyanide in water taken from streams within two days of the incident were between 37 mg/l and 58 mg/l and between 4,1 mg/l and 7,1 mg/l respectively. The oily material contained over 300 mg/l phenolic substances. Cyanide could not be determined in the oily material because of chemical interference. Further chromatographic analysis of the oil showed about 200 different chemicals, including alkenes, alkanes, aromatic hydrocarbons and their derivatives, terpenes, phenolic compounds, ketones, alcohols, ethers, esters, benzothiazoles, pyridines, anilines, amines, amides, quinolines, and sulphur compounds. After a year of self-purification and seasonal flooding, aquatic life had recovered. Analysis of a continuing oily leachate showed proportional increases in benzothiazoles and thiophenes and a reduction of terpenes and ketones.

Annex B
(informative)

Overview of water basin definition methods

Table B.1 — Characteristics of various water basin definition methods

Criteria		Method				
		Sandoz method[47]	Ciba method[36]	ICI method[11]	VCI method[12]	Australian method[41]
Method definition type		Deterministic	Deterministic	Deterministic	Deterministic	Probabilistic (risk-based approach)
Sizing parameter		0 m^3 to 5 m^3 per ton of material (tabulated)	3 m^3 to 5 m^3 per ton of material	Only estimation of expected water flows according to fire risk severity	Tables (general case) + specific tables for high-rise storages	Rainwater flow, fire-water flow for typical fire scenarios
General size of basins		Maximum 1 600 m^3	From 700 m^3 to 5 000 m^3, from standard curves	None defined	Tabulated	Two cases: sizing of a new facility and evaluation of existing capacity
Input parameters	Risk classification			Two categories of fire risk severity: — weak risk: 240 m^3/h to 1 000 m^3/h for 4 h — high risk: 1 620 m^3/h to 3 240 m^3/h for 4 h	Specific “Ki” rating	Input parameters according two logigrams explaining methodologies pertaining to case 1: design and assessment of new water basins, and case 2: evaluation of pertinence of existing water basin
	Hazard category of substances	15 categories			Specific classification of goods	
	Possible fire size	Limited to compartment size	Limited by the largest compartment (max 3 000 m^3)		Limited to compartment size	
	Possible fire duration		1 h for 200 m² to 5 h for 1 200 m²			
Additional measures	Use of sprinklers	Influence of basin volume only for pharmaceutical goods	Considered in storage limitation and in sizing			A fire safety study is part of the methodology and may lead to the consideration of additional measures
	Limitation of combustible materials	Limited to compartment size	Limited to 250 t or 600 m^2 if no sprinkler		Limited according to fire hazard	
	Detection and alarm systems					
	Additional feature		Consider water consumption for cooling		Consider water consumption for cooling	

Annex C
(informative)

Assessing water run-off containment capacities in existing facilities and facilities under development using risk-based approach — Australian method

The following diagrams are provided for a brief overview of the method. See Reference [9] for details.

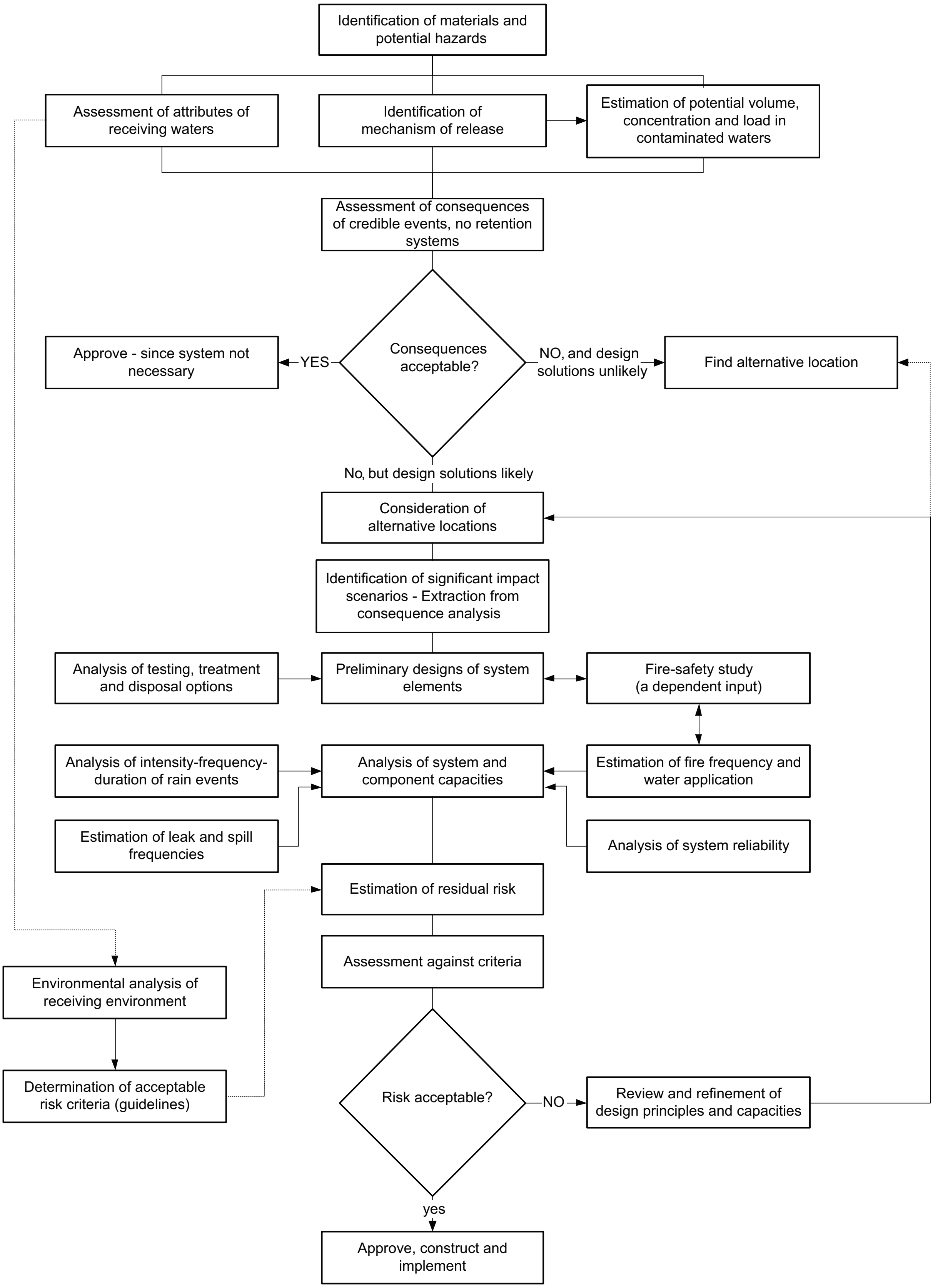


Figure C.1 — Flowsheet describing the implementation of a risk-based approach for the design and assessment of water-retention capacities in new facilities including sizing consideration (from Reference [9])

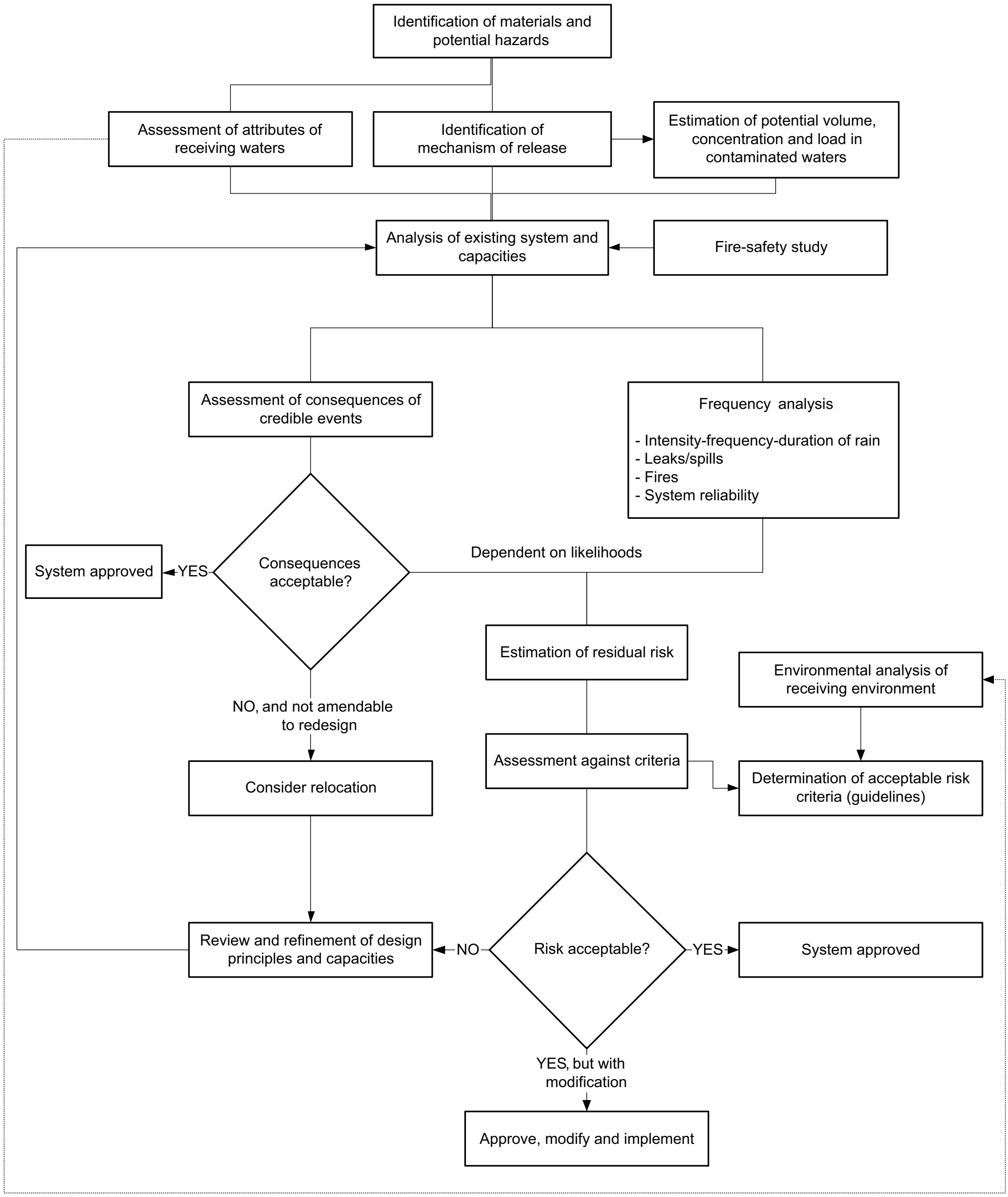


Figure C.2 — Flowsheet describing the implementation of a risk-based approach for assessing the existing water-retention capacities in operational facilities including sizing consideration (from Reference [9])

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