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DEVELOPMENT OF NEW WATER LANDING INFRASTRUCTURES AND PROCEDURES

J. Silva [1,2], P. Soares [1,2], V. Gabriel[1]
1. Universidade da Beira Interior, Aerospace Sciences Department (DCA-UBI), Calçada Fonte do Lameiro, 6201-001, Covilhã, Portugal
2. CiTUA, Instituto Superior Técnico, Universidade de Lisboa, Av. Rovisco Pais 1, 1049-001, Lisboa, Portugal

*** Corresponding author e-mail address**: jmrs@ubi.pt

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ABSTRACT

Over the past years Portugal has experienced several accidents involving water landing and ditching emergencies, some fatal, which involved an in-depth study of the process of water landing and its specificities. Thus there is a failure regarding the characteristics of the dedicated water landing infrastructures, as well as an effective risk assessment and flight crew training. This study addresses an analysis of historical occurrences and the lessons retrieved up from them, but also the current applicable regulations to propose new water landing infrastructures equipped with operational support elements that could assist aircrafts in regular operations as well as emergency situations, if the decision is to ditch the aircraft. For this purpose, two locations are proposed for such infrastructures at two distinct dams, Marateca and Aguieira. The proposed location is based on the initial condition that the areas for operation are well defined and marked out, thus avoiding the risk of incursion into them by third parties who are unaware of the delimitation of these restricted areas of operation. It also accounts for the existence of means of rescue, especially in the event of an accident, namely search and rescue means for immediate reaction. It is also proposed to build up the infrastructure on the 'land side' with hangars, parking bays and taxiways, which can be used by amphibious or rotary-wing aircraft, while aircraft/crews can move from the maritime to the land environment via docks or access ramps. Means for ensuring safety and separation of "airside" to the "landside" are also proposed. This study is based on the requirements of international and national legislation, which include theoretical and practical training, as well as key points that must be addressed during the training stage. In addition, these points are based on the prerequisites needed to obtain an amphibious aircraft pilot's licence.

Keywords: Amphibian Aircraft; Emergency Response; Risk Assessment; Pilot Training and Regulations; Water Landing.

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GENERATIVE AI USAGE STATEMENT

This research did not use generative AI.

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1 INTRODUCTION

Recently Gabinete de Prevenção e Investigação de Acidentes com Aeronaves e de Acidentes Ferroviários (GPIAAF), as it is their obligation according to the Portuguese Decree-Law 318/99 of August 11th (Decreto-Leinº 318/99 de 11 de agosto) and with the Portuguese Decree-law 36/2017 of March 28th (Decreto-Leinº 36/2017 de 28 de março), has publicly shown concern at the underestimation by the Portuguese aviation community of its recommendations in the context of past accidents involving ditching manoeuvres (GPIAAF – Unidade de Aviação Civil, n.d.). This concern is the motivation for conferences at flight schools – ATO, such as Aeronautical Web Academy (AWA), (Figueiredo, 2022), in order to raise awareness among flight crews so that, with access to information, they can better react to these emergency situations.

According to GPIAAF there are some aircraft ditching myths that are still present in the pilot community. From "Low wing aircraft are easier to ditch" to "It is impossible to evacuate the aircraft before it sinks", these ideas should be deconstructed due to the lack of evidence and statistics that do not support them. The decisive factor that should always be taken in consideration in the ditching manoeuvre is the use of proper techniques (Figueiredo, 2022). As such, a new way of perceiving safety should be addressed, with new methods for risk assessment and consequent changes to the syllabus in the specific training of this manoeuvre.

Since Portugal has vast water resources, it could be suggested that pilot training and education (at an advanced stage) could take these resources into account, starting with using them for emergency landings. A study could also be carried out on the introduction of new water landing sites, with suitable infrastructure, to see if overall flight safety would improve in light-aircraft operations, across their various forms and applications.

When idealising these type of infrastructures and its location, a study of the site should be carried out to check its compatibility with the project to be developed. Some of the factors that are usually checked in other countries, among many others are: the maritime movements at the site, including currents and swell; the relationship between the depth of the bottom of the water mirror on the proposed water runway; and the available length of the runway that is obstacle-free and safe in relation to the size and aircraft to be used (ICAO, 2014). Also, space to install typical infrastructure such as a hangar, a fuel tank, one or more floating docks, a ramp, one or more buoys, at least one assistance/rescue vessel and a small maintenance facility (Seaplane Team, n.d.) should be provided for the creation of an amphibious aircraft base. Despite all this, pilots can only take advantage of these sites by having proper training since ditching is considered to be a dangerous manoeuvre for inexperienced flight crews (Figueiredo, 2022).

According to the experts, there are lot of factors that should be considered when water landing. Among them: wind direction and speed; presence of swell and, if present, direction of their movement;, and the pilot's skills, training and experience. Additionally, the aircraft performance and characteristics should not be forgotten or underestimated (Ministry of Education and Science of Ukraine, & National Aviation University Flight Academy, 2020). Therefore, pilots must receive specific training not only to be able to take advantage of water landing sites, but also to correctly assess the risks in preparation for each mission.

2 LITERATURE REVIEW / THEORETICAL FRAMEWORK

ICAO was founded in 1944 when the Convention on International Civil Aviation (Chicago Convention) was signed. Today ICAO is a UN organisation specializes in establishing international standards, recommended practices and procedures covering all aspects of international civil aviation operations. This organisation cooperates closely with its 193 state members to reach consensus on Practices and Policies to ensure a safer, more efficient and more economically and environmentally responsible aviation operation. The Convention resulted in a series of articles that materialize through 19 documents called ICAO Annexes. Portugal was one of the first 52 states to sign the Convention on December 7th, 1944. According to the Article 26 of this Convention, each contracting state should undertake investigations of accidents and incidents that occur in its territory with the purpose of prevent similar accidents (ICAO, 1944). In order to carry out those investigations, ICAO issued the first edition of the Annex 13 – Aircraft and Incident Investigation in 1951 (ICAO, 2022). This document – and its current 13th edition (2024), provides standardized, specific guidelines and procedures to be approached by state members on those investigations. It is important to mention that the sole objective of the investigation of an accident or incident shall be the prevention of accidents and incidents. It is not the purpose of this activity to apportion blame or liability (ICAO, 2022). In this context, each state should constitute an AIA – Accident Investigation Authority, that operates within the vision of the documents issued by ICAO. This AIA should operate independently from the national aviation authority or any organisation, whose interests or duties may conflict with the mission entrusted to it or influence its objectivity. In Portugal, that organisation is Gabinete de Prevenção e Investigação de Acidentes com Aeronaves e de Acidentes Ferroviários (GPIAAF, n.d.). By researching into previous water landing accidents, similar recommendations are revealed, emphasizing key aspects that can be implemented by both operators and authorities. As such, the importance of addressing new water landing infrastructures and procedures available in other countries and other operators becomes evident. This research can provide a glimpse into what could be developed in Portugal and its significance on overall flight safety. This research could also be integrated into flight school training, to assist pilots in training for ditching manoeuvres, in the beginning of the training. By incorporating this knowledge, pilots can better prepare for emergency situations involving ditching and enhance their ability to respond effectively.

Amphibian aircraft can be a valuable asset for practical and recreational purposes. In addition to this, they can be used in special flight activities, such as firefighting, evacuation of people and delivering food or medical supplies. The ability of taking-off or landing in water, makes them extremely versatile, allowing their operation on remote areas or even in regions that lack proper airport infrastructure. In locations where water aerodromes are available, this kind of aircraft can both combine the advantages of an aircraft, such as speed, with the ones related to boats, such as accessibility (DGCA Indonesia, 2013).

According to ICAO, an Aerodrome is *“a defined area on land or water (including any buildings, installations and equipment) intended to be used either wholly or in part for the arrival, departure and surface movement of aircraft”* (ICAO, 2022:1-2). This definition, however, only refers to aerodromes in general, regardless of the type of surface for landing and ground manoeuvres. Since the operations to be carried out in land or water airports differ significantly, it becomes important to set different standards regarding water aerodromes certification. As such, on water aerodromes, a different approach on necessary facilities, services and equipment should take place (ICAO, 2018). The Asia Pacific Regional Guidance on Requirements for the Design and Operations of Water Aerodromes for Seaplane Operations defines Water Aerodrome as *"A defined area, primarily on water, intended to be used either wholly or in part for the arrival, departure and movement of seaplanes, and any building and equipment on ground or water"* (ICAO, 2018:1). There are many examples of water aerodromes around the world, as such, by comprehending how other countries develop this kind of infrastructures, a general idea of what needs to be built can be perceived. Additionally, since some of them were established a long time ago, their expertise on the matter is fundamental to ensure that their bases are the safest as they can be.

Also flying an amphibious aircraft is, in most ways, similar to piloting a land aircraft. However, the most notorious difference between landing in a static surface such as tarmac and landing in a mutable surface such as water is all the considerations to be aware off prior to the manoeuvre. The variables in this changing environment can be the water conditions, wind direction, presence of floating debris, boat traffic, among others (Fly the Shark, n.d.). Due to several operation differences, pilots must obtain an amphibian aircraft rating to be able to pilot them. This additional training ensures pilots that additional manoeuvres that differ from land aircraft are addressed and trained. Also, this ensures their proficiency in operating in the water environment, considering all the additional variables associated with it. In Europe there are many flight organisations specialized in this specific training and operation.

The examples of aircraft accidents related to water landings or ditching highlight significant gaps in Portuguese emergency support infrastructure which currently, and according to the reports presented, rely heavily on the occasional presence of nearby individuals during SAR operations. In order to address this gap, two different existing infrastructures were analysed. The Lake "*Hood Seaplane Base*", in Alaska is the largest one of its kind and as such is extremely well equipped with operational and support infrastructure carefully placed to better aid pilots flying to this location. Since the water landing infrastructures to be proposed in this study are going to be proposed in a dam, a smaller sized amphibian aircraft base was researched. The Lake "*Como Seaplane Base*" in Italy evidenced that even with fewer infrastructure the regular flying and training operation is still feasible by contemplating the key aspects regarding the available equipment on-shore, shoreside and off-shore. This ensures that safe flight activities are carried out effectively, even with minimal infrastructure, by prioritizing essential operational elements and strategic resources, such as a maintenance hangar and commodities for pilots. It was also evidenced the importance of a careful, detailed pre-flight phase with proper water landing site assessments, including evaluation of water conditions, potential obstacles, and hazards such as flying birds or electrical power cables. To complement this, the need for new procedures to be included in basic pilot training regarding water landing procedures is key to ensure that such manoeuvres, whether in emergencies or regular contexts are performed safely. For this reason, general guidelines for amphibian aircraft operators and ATOs shall be provided in a way that the specific operational requirements of each operator can be added subsequently. This ensures that safety protocols and training are tailored to their unique contexts while maintaining a standardized framework for compliance and best practices.

3 METHODOLOGY

This study comprises three distinct phases. The first one relates to better understand the current state of the art. At this phase, the referenced Bibliography was analysed. Reports published by GPIAAF that are related to ditching events were analysed too, especially their conclusions and recommendations. At this stage, the research of existing water landing sites was analysed. As such, not only the research into the legislation and regulations related to this aspect was conducted but also contact with air operators or providers that have experience in the aquatic environment, in particular, in water landings, toke place. Some of these operators are contracted for rural firefighting operations through the coordination of the Autoridade Nacional de Emergência e Proteção Civil (ANEPC, n.d.) as a state resource for this purpose. By contacting them, it was also possible to gather information on water landing improvised sites that are being used as of today for water retrieving manoeuvres, that is, scooping. Furthermore, the Autoridade Nacional da Aviação Civil (the Portuguese National Authority of Civil Aviation - ANAC), was contacted, to better understand which are the applicable legislations to this kind of infrastructures.

The second phase is based on the previous one. With the information gathered, the objectives proposed started to be addressed, that is, evaluation of International, European and Portuguese requirements necessary to design and ensure the operation authorization and eventually grant the certification of these water landing locations. The same process was applied to training content that comprises also the risk assessment material as well.

The third and last phase involved producing a proposal for two water landing infrastructures at two Portuguese dams. The decision to place each element in the infrastructure was subjected of a critical and duly justified choice. Furthermore, the eventual production of a procedural training guide to be used in the proposed infrastructure will be based not only on the regulations analysed in the second phase, but also on documentation produced by other countries that face this reality on a daily basis and that have studied it, particularly Asian countries.

4 CASES STUDY: MARATECA AND AGUIEIRA DAMS

At this time no dedicated or approved water landing sites exist in Portugal. As such, the content developed in this section aims to address this gap by proposing the implementation of water landing infrastructures as two selected dams in the country. By proposing these facilities, the dam's utility will be enhanced, by promoting water-based operations, contributing also for local economy. This development should consider careful planning and design to ensure that the infrastructures are safe, regulatory compliant and an asset for aircraft operation in Portugal. As of today, dams are designated by ANEPC only for scooping maneuvers in firefighting operations. By extrapolating this to civil aviation, not only regular water landing operations can be conducted, but also crucial emergency ones related to emergencies in non-amphibian aircraft. In the event of an in-flight emergency such as engine failure, these sites could provide for a safe ditching option, when compared to uncontrolled water landings. Since the proposed infrastructure shall be equipped with emergency response capabilities, the safety of emergencies in flight operations in the region will increase by reducing the risks associated with emergency water landings. For the Water Landing Infrastructure design, the Cessna 208 Grand Caravan EX Amphibian (Table 1) was chosen due to its high versatility, which includes an amphibian version. This is a single-engine turboprop designed and produced by Cessna, a commonly known and established manufacturer. This aircraft will be considered as the design aircraft as the most critical aircraft in terms of dimensions, it is not a large aircraft such as a Canadair, but not as small as a Cessna C152 (Africair, 2021). And because of that, the infrastructure shall comply with all terms of is characteristics.

Table 1: Cessna 208 Grand Caravan EX Amphibian Characteristics. Source: Africair (2021)

Dimensions	Wingspan	52 ft 1 in	15.87 m
	Length	41 ft 7 in	12.67 m
	Height	17 ft 5 in	05.31 m
Engine	P&WC PT6A-140	867 shp	(Shaft Horse Power)
Weights	Max. Take-off Weight	9062 lb	4110 kg
	Empty Weight	5975 lb	2710 kg
	Useful Load	3122 lb	1416 kg
Performance	Take-off Ground Roll	1826 ft	557 m
	Take-Off Water Run	2000 ft	610 m

Table 1 has no values for the Landing run. Indeed, the take-off run distance is more critical for water landings due to the aggravated drag that amphibian aircrafts experience because of the presence of floats. The performance values for this aircraft are based on zero wind conditions. This aircraft is equipped with the Wipline 8750 floats, that have a hull hight of 3 ft 3 in (0.99 m) and a hull width of 3 ft 6 in (1.07m), (Wipaire, Inc., n.d.). To effectively take advantage of the proposed water landing infrastructures, specialized training for pilots and emergency response teams is essential. Water landings, particularly for non-amphibian aircraft in distress, pose unique challenges, not faced on in-land operations. Water landing training shall comprise a controlled landings and take-offs, ditching and safe evacuation procedures, while coordinating with on-site emergency responders. By considering a comprehensive water landing training, this aims not only to ensure that these requisites are met, but also that the proposed infrastructures can be used safely and effectively for both routine and emergency situations, consequently enhancing overall aviation safety in the region.

The Santa Águeda Dam, also known as the Marateca Dam, is located between Fundão and Castelo Branco municipalities. At its maximum level, the flooded area is approximately 634 hectares. This reveals that this could be a candidate for the implementation of water landing infrastructures. In spite of this, wildlife is abundant at this place and as such, for considering the implementation of such infrastructure, can be challenging in this regard. This forces the developer to ensure that wildlife mitigation efforts are being carried out (Aldeias de Montanha, n.d.). For the dam to be able to accommodate a dedicated water landing area, a certain length based on the most critical aircraft to be used at this water landing infrastructure, must be ensured. For this, and considering the prevailing wind direction, based on the data from the previous 30 years, a runway can be defined. In spite of this, it is clear that a speed of 5 km/h to 10 km/h (2.7 knots to 5.4 knots) is most frequent, making this dam a suitable location for the implementation of a water landing infrastructure, in this direction.

The Aguieira Dam, is a major hydroelectric infrastructure on the Mondego River, located between Coimbra and Viseu districts. This dam was completed in 1979 and inaugurated in 1981 and stands 89 meters high, 400 metres across, making this a substantial infrastructure for its class. Also, fishing enthusiasts can discover many secluded spots for their activities. This presents an additional challenge regarding water operations due to the presence of obstacles such as boats on the water. As such, steps for hazard mitigation must be ensured in this regard. As an additional fact, when this dam was filled, it submerged several villages, such as Breda and Foz do Dão (Structurae, n.d.). Because of this, a study of the bottom obstacles should also be performed. The same study of the prevailing winds is also necessary for the reasons already mentioned. As so, as based on the available 30-year data, the runway and the adjacent areas can be established. In this dam, the prevailing winds have the direction of E-W, with windspeeds of 2 km/h to 30km/h (1 knot to 30 knots). In spite of this being the prevailing wind, due to the dam physical characteristics, the infrastructure alignment must be changed. As such, the second most prevailing wind figures are to be considered, with the direction of WNW-ESE and speed of 2 km/h to 20 km/h (1 knot to 11 knots). By choosing to propose the runway in this direction, additional operational challenges arise, such as landing/taking-off during crosswind conditions. That's why it is important to ensure a proper support infrastructure to aid pilots to operate safely under these conditions. The development of the operational and support infrastructure needs to account for the shoreline characteristics. Since the coastal typology is different from the case studied previously (Marateca), being less flat, the infrastructure is more limited. Due to this fact, the land where the necessary support means are proposed to be established, needs to be flattened, resulting in a more onerous development.

5 RESULTS

As any other aircraft operation, also while operating in water landing sites, it is still necessary to make considerations regarding the different flight phases. This study provided a guide for operation assessment for the most critical phases too, that should be addressed when pilots are trained to make use of the proposed infrastructure. The different mission flight stages are: Pre-flight; Take-off; In-flight; Landing; and Post-Flight. Each flight stage comprises different, but important procedures, that should be clearly outlined for a successful mission. Regarding the proposed infrastructures, the most critical phases are the pre-flight (for preparing the mission and perform risk assessment considerations as well as the emergency procedures discussion), take-off and landing. Even though it is not a critical stage, the post-landing procedures are also important to flight crews be able to take advantage of the support facilities.

In this study two different water landing infrastructures were proposed, but most important, identify the minimum necessary dedicated support facilities. These were also proposed to address the current lack of such facilities in Portugal. By considering safety considerations, regulatory compliance and operational effectiveness, the proposed designs can be positioned as a valuable asset for aircraft operations in this context. For the correct implementation of the mentioned infrastructures, illustrative diagrams were outlined as well as particular characteristics of the equipment. Considerations regarding limitations of the chosen locations were also addressed. Even though the study was limited to 2 dams, the contend developed in this study provides significant insights of the infrastructure and equipment necessary to develop similar facilities in other enclosed spaces. Furthermore, by providing these infrastructures with emergency response capabilities, they could not only support regular amphibian aircraft operation but also offer critical emergency options for non-amphibian aircraft in distress. Training/Procedural considerations were also exposed, with the aim of providing pilots an insight of the requirements that they should master operate at the proposed infrastructures in a safe and efficient manner. According to the applicable SEP/Sea Class Rating and Portuguese regulations, a theoretical and practical instruction programme shall be implemented with the topics approached in this study. This initiative is, therefore, a step forward in enhancing aviation safety in those regions, providing the possibility for controlled, well-equipped environments and infrastructures for water landings, thereby reducing ditching related hazards.

6 DISCUSSION

Based on the research, it was concluded that there is no certified or even authorized mooring infrastructure in Portugal. Therefore, implementing such infrastructure is challenging, requiring a careful analysis of existing and applicable international standards and guidelines, adapting them to the Portuguese reality.

Through these studies, it was possible to identify two locations capable of protecting such infrastructure and potentially equipping them with best practices and recommendations. Therefore, the Marateca and Aguieira Dams were selected. These locations allowed the installation of runways, restricted areas, and support infrastructure, such as hangars and fueling services.

Educational materials related to the use of these infrastructures were also developed, enabling their operational use in a safer and more responsible manner, whether for planned and "normal" operations or in emergency situations.

7 CONCLUSION

According to the content developed in this study, it was demonstrated that the implementation of mooring infrastructures in the context of dams in Portugal could serve not only to resume amphibious operations in the country, but also serve as an operational base for emergency air operations.

It was concluded that the implementation and operation of such infrastructure requires careful planning, first and foremost in compliance with current standards and regulations, to ensure the operations it hosts are carried out as safely as possible—with the addition of additional layers of safety, such as separating the operational area from the recreational area with visual markers, or implementing adequate emergency resources not only on the "landside" but also on the "airside." Remember, and always keep in mind, as an initial consideration, the characteristics and performance of the aircraft selected as the "critical aircraft," which will determine the sizing of the operational areas, obstacle clearance, and support for air operations.

Additionally, a training and procedural development guide will also be required to maximize the proposed infrastructure safely and responsibly, where risk is acceptable. These procedures must be based not only on the prior training required for pilots to obtain amphibious aircraft qualification endorsement, but also on the specificities of each aircraft in terms of procedures to be performed before, during, and after the completion of each mission.

Thus, it was concluded that these infrastructures can increase the interest that once existed in amphibious operations, but also increase flight safety for aircraft in sensitive emergency situations. The latter scenario is feasible by providing pilots with an infrastructure that is properly publicized in aviation circles and capable of fully responding to an emergency situation, given that adequate emergency resources are readily available.

Since there is currently no dedicated infrastructure of this kind in Portugal, its implementation could translate into new opportunities, whether for aviation schools, firefighting operations, or even for sports and recreational purposes. All of these possibilities can and should be analyzed in future work, namely: (a) focusing on the study of Mooring Infrastructures in a maritime and river context, to be able to verify their viability in areas with strong currents and waves, as well as in other non-confined areas; (b) studying the Environmental/Noise/Aquatic Impacts, to understand the influence of the implementation of this type of infrastructure on the ecosystem and residential areas bordering the chosen location; (c) studying the Economic Impact/Cost-Benefit Analysis, to better understand whether the development of such infrastructures can translate into economic growth and regional development; and (d) Analyzing the feasibility of the proposed Risk Assessment/Training and Qualification Guide with aviation schools, in order to evaluate the possibility of including such training supplements for all untrained pilots.

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