

Fact Sheet on PUB’s Directed Request for Proposal (RFP) 19/01 on Low-Energy, Low-Chemical Pre- and/or Post-Treatment for Seawater Desalination

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Background

1. The Competitive Research Programme (CRP) (Water) is a competitive funding scheme under the Urban Solutions & Sustainability (USS) domain as part of RIE2020. The aim of the CRP (Water) is to fund basic / applied R&D projects, which possess recognisable potential for developing into innovative solutions for the water industry.

Present Call

2. Currently, Singapore uses approximately 430 million gallons of water per day (mgd). By 2060, the water demand is projected to double, and seawater desalination is expected become a major source of Singapore's water then. Sustainability and reliability of our water resources hence is critical to the long-term and continued growth of Singapore.
3. In view of the growing dependence on seawater desalination (which is an energy-intensive treatment process), energy efficiency for desalination has been a key research priority for Singapore. The current state-of-the-art seawater desalination plant consumes about 3.5 kWh/m³ at about 50% recovery (Refer to **Appendix 1** for flowchart of a typical seawater desalination process). Through R&D, the short-term goal is to reduce the energy consumption for seawater desalination to less than 2 kWh/m³ at the system level. To achieve this, significant research efforts have been directed to improve the main desalting step through innovative solutions, such as biomimetic membrane and electrochemical deionisation, and increasing energy recovery, such as harvesting the osmotic difference between two waste brine streams via pressure retarded osmosis.
4. The pre- and post-treatment for seawater desalination typically consumes about 1 kWh/m³. This is as a potential area for improvement, which has not been studied as intensely as the main desalting step, and hence warrants further investigation.
5. This directed RFP hence solicits **low-energy and low-chemical** solutions for A) **pre-treatment processes**, and B) **post-treatment processes (particularly boron removal)** for seawater desalination.

Focus Area A: Pre-treatment

- Pre-treatment herein refers to processes that treat raw seawater before seawater reverse osmosis (SWRO) process. Typically, pre-treatment for SWRO consists of screens, dissolved air flotation (DAF) and ultrafiltration (UF) process, with an

energy consumption of about 0.5 kWh/m³. Various chemicals, e.g. H₂SO₄, FeCl₃, NaOH, NaClO, etc., are used in processes of coagulation, flocculation as well as cleaning-in-place (CIP). Please refer to **Appendix 2** for flowchart of pre-treatment for seawater desalination.

- PUB is soliciting solutions that can enhance the effectiveness and/or efficiency of pre-treatment for seawater desalination. The technologies proposed shall show how it uses less energy and/or less chemicals as compared to the standard treatment train (i.e. **Appendix 2**). Typical water quality of raw seawater (as feed for the pre-treatment) is provided in **Appendix 3**. The filtrate of the proposed solution shall meet SWRO feed quality (please refer to **Appendix 4**).
- Algae bloom is one of the operational issues that desalination plants face seasonally as well. Algae bloom results in higher chlorophyll-a counts in the intake seawater and the consequential impact would be having to backwash and perform CIP more frequently for pre-treatment and SWRO processes respectively, thus, reducing the plant's capacity. The proposed solutions shall be resilient against algae bloom.

Focus Area B: Post-treatment (particularly boron removal)

- The main purpose of post-treatment is to further remove boron from SWRO permeate to meet drinking water quality standard (≤ 0.5 mg/L). Boron removal is typically done through a brackish water reverse osmosis (BWRO) process, where 70% permeate of SWRO is further treated. The energy consumption of post-treatment is about 0.5 kWh/m³, with NaOH added to adjust the pH of SWRO permeate to enhance the boron removal efficiency. Please refer to **Appendix 5** for a typical process flow chart of post-treatment.
- PUB is soliciting solutions that can enhance the effectiveness and/or efficiency of post-treatment (particularly boron removal) for seawater desalination. The technologies proposed shall show how it uses less energy and/or less chemicals compared to the standard treatment train (i.e. **Appendix 5**). Besides boron, the product water of the proposed solution shall also meet the requirements of drinking water quality standards¹.

6. Proposed solutions related to main desalting step as an alternative to the existing (commercial) SWRO, which can improve and/or optimise the overall desalination treatment process, will also be considered in this RFP.

¹ The product water quality shall meet the Environmental Public Health (EPH) (Water Suitable for Drinking) (No.2) Regulations 2019, with details to be found in following website:
https://www.pub.gov.sg/Documents/Singapore_Drinking_Water_Quality.pdf.

7. All the proposals submitted shall articulate the advancement of the proposed technology against the current global state-of-the-art at the system level. The Technology Readiness Level (TRL) of the proposed technologies has to be stated in the proposal. At the end of the project, the TRL is expected to progress by at least two levels, unless otherwise justified in the proposal. Please refer to **Appendix 6** for the definitions of TRLs.
8. Despite focusing on pre- and post-treatment, the proposal is required to address how the proposed technology fits into the overall treatment process for seawater desalination. Its anticipated performance in terms of energy consumption (kWh/m³), chemical usage (kg/m³), water recovery (%), water quality, sludge generation (kg/m³), and land footprint (m²/m³), etc., has to be addressed at the system level. These envisioned seawater desalination treatment process and its corresponding performance shall form part of project deliverable².
9. All research activities have to be carried out in Singapore. Cross-disciplinary and multi-disciplinary research proposals are strongly encouraged, as well as proposals from research consortia involving partners drawn from different private and public organisations and academic institutions, including international collaborations with renowned experts to introduce new research capabilities and transfer of technical expertise to Singapore.
10. R&D proposals already funded by other agencies or being considered for funding by other agencies will not be considered under the present call. PIs will need to declare other funding sources in the application.

Eligibility Information

11. This call is open to Institutes of Higher Learning (IHLs), Research Institutes (RIs) and private sector companies based locally in Singapore. Under this Directed RFP, IHLs, public sector agencies and not-for-profit RIs will qualify for 100% funding support of approved qualifying costs, while private sector companies and for-profit research entities will qualify for up to 70% funding support of approved qualifying costs.

Application Procedure

12. To apply, the applicant must submit the proposal using the ‘CRP (Water) Research Proposal Form’, which can be downloaded from the online Integrated Grant Management System (IGMS)³. Please refer to **Annex A** for detailed guidelines for the submission of the Proposal and **Annex B** for guidance on creation of account in IGMS.
13. The proposal shall include, but not limited to:

² Subject to the TRL of the proposal, the deliverables can be either in the form of calculated performance for low TRL project or actual operational data collected from a pilot plant for high TRL project.

³ <https://researchgrant.gov.sg>

- i. Scientific principles
 - ii. State-of-the-art comparison, including a technical review of the technology proposed against the latest technologies.
 - iii. Full technical details on the methodology and technological development of the proposal, e.g. if the technology will start from bench-, to pilot-, to demonstration-scale level of development, and to eventual commercialisation. The applicant should also consider the proposed technology in a holistic system approach (i.e. the requirements of the technology as a system if it is to be implemented).
 - iv. Commercial viability of the project, including target markets for application of the technology or findings from the project.
 - v. Clear description of general business plan that addresses items such as, but not limited to, competitive analysis, go-to-market strategy, revenue model, commercialisation plan, as well as manufacturing and validation at scale. The plan should also highlight how the Intellectual Property (IP) created will be owned and commercialised, and how the benefits from these commercialisation plans can be accrued to Singapore.
 - vi. The proposed team members' expertise, previous related work and experience (2-page CVs shall be submitted for the Lead PI, as well as for all co-PIs and collaborators, using the format specified in **Annex C**).
 - vii. Detailed budget required for the project (broken down into individual categories of manpower, equipment, consumables, travel, consultancy services, others).
 - viii. Timeline for the project, showing intermediate milestones to be achieved.
 - ix. Expected research outputs and outcomes, and proposed key performance indicators (KPIs) for the project.
14. Please refer to **Annex D** for the details of non-fundable direct costs for CRP (Water) projects.
15. The deadline for the Proposal submission is on **24 February 2020, 4:00 pm** (Singapore time, GMT +08:00).

Evaluation Criteria

16. Proposals received shall be sent to international peer reviewers for technical/scientific merit review. If appropriate, proposals from academia may also be sent to Industry Resource Persons (for commercial viability) and relevant national agencies (for national relevancy) for review. This is then followed by evaluation by CRP (Water)'s Project

Evaluation Panel (PEP), which comprises local and international members. The PEP shall evaluate the proposal based on the criteria given in Para 17, referencing reviews from international peer reviewers, and recommend projects for funding support.

17. All Proposals are evaluated against the following criteria:

- i. Excellent science and cutting-edge technology with proposed activity involving innovative and cutting edge research that seeks to bring together the best R&D talent available.
- ii. Significant economic or social benefits to be accrued to Singapore through either tangible measures (creation of IP, start-up companies, spin-out enterprises, etc.) or potential for commercialisation into new products/services/ technologies deployed to solve national needs.
- iii. Robust management and governance, with adequate checks and balances, a clear structure of accountability, as well as reasonable milestones and deliverables.
- iv. Reasonableness of the proposed budget.

Estimated Budget

18. Funding support for each Research Proposal awarded shall not exceed **S\$2.5 million**. The Applicant should contribute in-kind services, cash, or a combination of the two towards the proposed project. In-kind services can include manpower, materials, and other services. In-kind contributions demonstrate the participation and commitment of the applicants to the project.

Maximum Project Duration

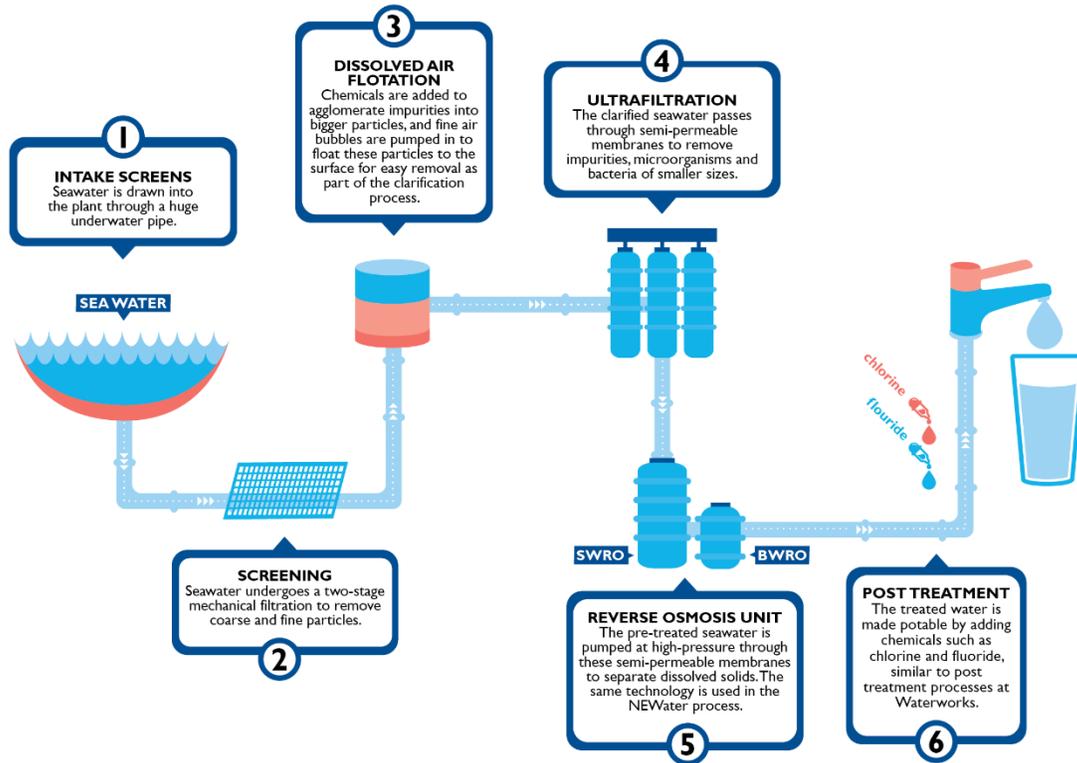
19. The maximum funding period for each Research Proposal is **3 years**.

Point of Contact

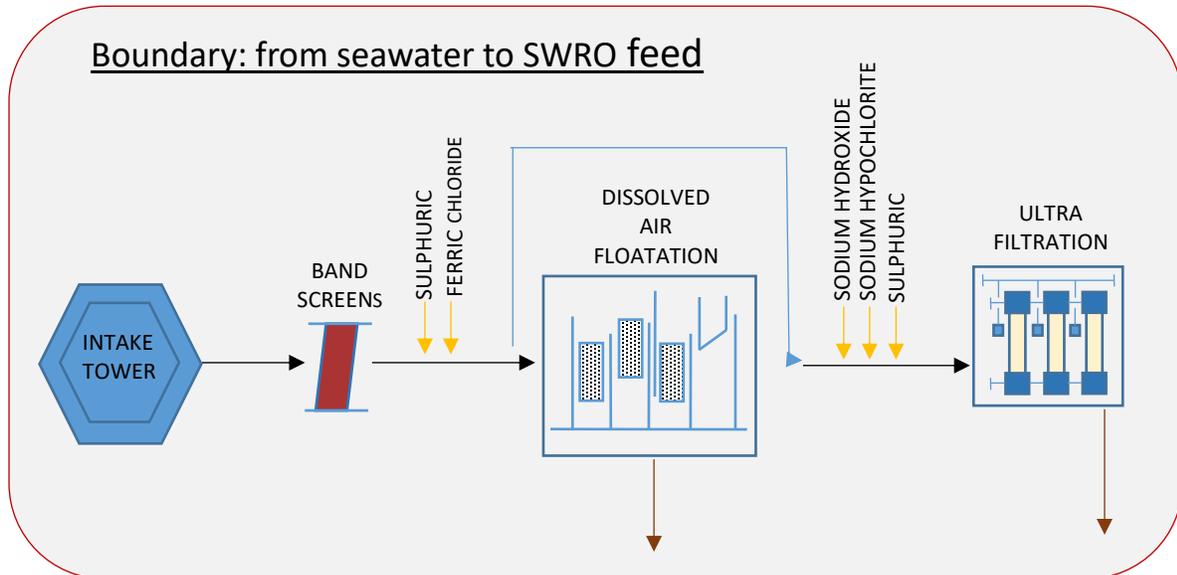
20. For more information, please contact Ms Gu Yan (GU_Yan@pub.gov.sg) or Dr Huang Yinxi (HUANG_Yinxi@pub.gov.sg) from PUB Singapore.

~ End ~

Appendix 1: Flowchart of typical seawater desalination process



Appendix 2: Pre-treatment Process of Seawater Desalination



Appendix 3: Typical Water Quality of Raw Seawater

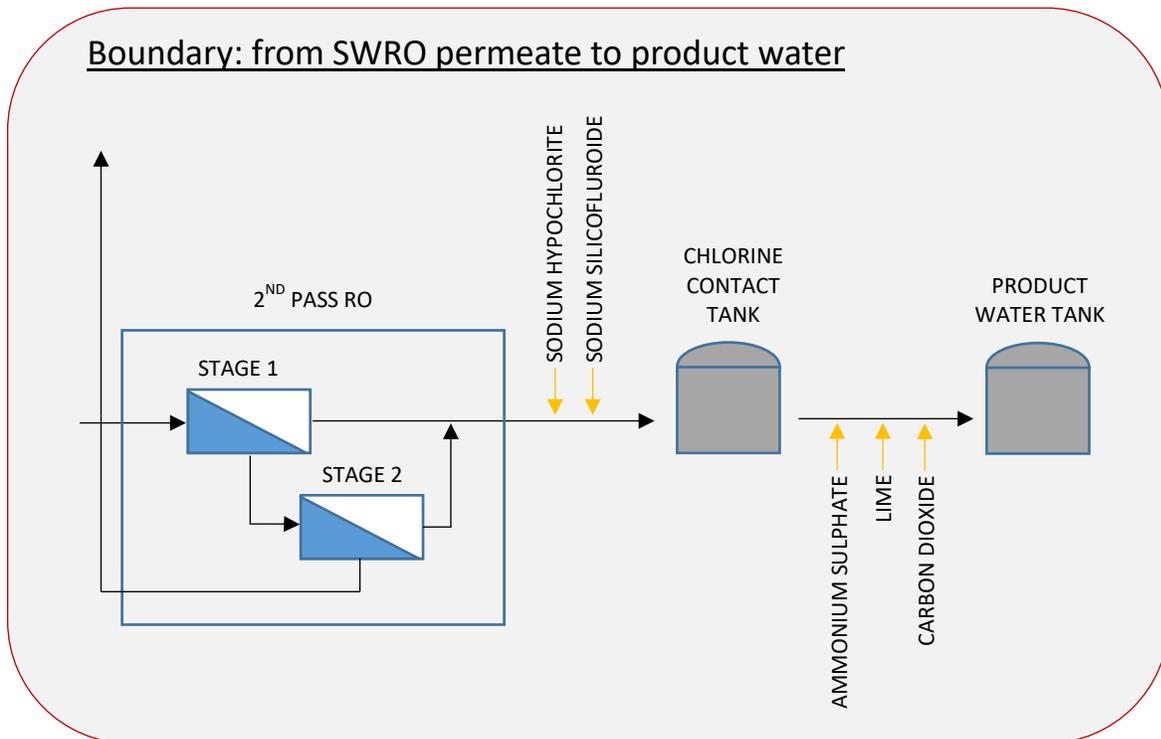
S/N	Parameter	Unit	Value
1.	pH	-	8.0 – 8.3
2.	Total Dissolved Solids	mg/L	30,600 – 35,700
3.	Specific Conductivity	µS/cm	47,089
4.	Total Suspended Solids	mg/L	2.8 – 49.3
5.	Turbidity	NTU	0.4 – 27.2
6.	Chemical Oxygen Demand	mg as O ₂ /L	6.0 – 72.0
7.	5-day, 20°C Biochemical Oxygen Demand	mg as O ₂ /L	2.00 – 10.00
8.	Total Organic Carbon	mg/L	0.08 – 4.22
9.	Dissolved Organic Carbon	mg/L	1.60
10.	Total Nitrogen	mg/L	< 1.00
11.	Nitrite	mg as N/L	< 0.02
12.	Nitrate	mg as N/L	0.50 – 4.97
13.	Total Phosphate	mg as P/L	0.13 – 1.00
14.	Dissolved Phosphate	mg as P/L	0.06 – 0.82
15.	Total Alkalinity	mg/L	101 – 116
16.	Total Hardness	mg/L as CaCO ₃	5,360 – 7,910
17.	Bicarbonate	mg/L as CaCO ₃	99 – 114
18.	Oil & Grease (via method infrared absorption)	-	0.3 – 3.3
19.	UV absorbance (254 nm)	-	< 0.05
20.	Aluminum	mg/L	0.70 – 2.33
21.	Ammonia	mg/L as N	< 0.05 – 0.11
22.	Barium	mg/L	< 0.01 – 0.515
23.	Boron	mg/L	1.81 – 7.44
24.	Calcium	mg/L	366 – 552
25.	Chloride	mg as Cl ⁻ /L	14,300 – 19,200
26.	Fluoride	mg as F ⁻ /L	0.42 – 1.00
27.	Iron	mg/L	< 0.19 – 0.74
28.	Manganese	mg/L	< 0.05 – 0.58
29.	Magnesium	mg/L	1060 – 1620
30.	Potassium	mg/L	352 – 593
31.	Silica	mg/L as SiO ₂	0.11 – 1.05
32.	Sodium	mg/L	8,290 – 13,400
33.	Strontium	mg/L	6.3 – 10.3
34.	Sulfate	mg as SO ₄ ²⁻ /L	2,350 – 3,450
35.	Heterotrophic Plate Count	cfu/mL	10 – 16,100
36.	Total coliforms	cfu/mL	46 – 37,000
37.	Fecal coliforms	cfu/mL	6 – 79
38.	<i>E. coli</i>	cfu/L	< 416

Appendix 4: SWRO feed quality requirements

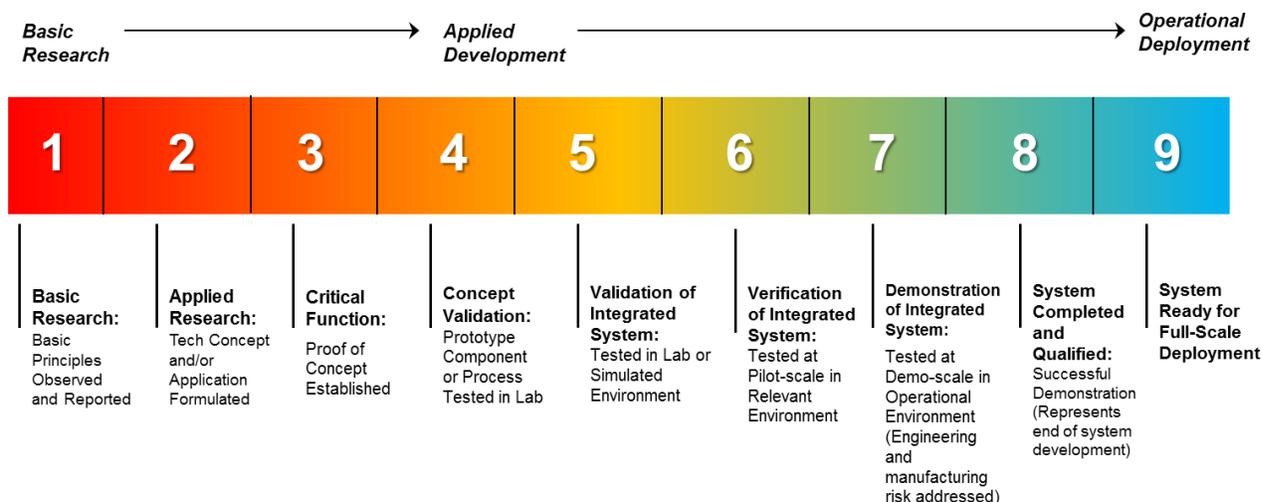
The product water after pre-treatment process (filtrate) as feed for SWRO stage shall meet the following requirements:

- a) The filtrate turbidity for any 24-hour period shall not exceed 0.1 NTU 95% of the time and shall never exceed 0.2 NTU.
- b) The fifteen minute Silt Density Index (SDI₁₅) of the filtrate shall not exceed 3.0.
- c) The system shall demonstrate as a minimum:
 - 4 log (99.99%) removal for particles in the 3 µm range or larger.
 - 4 log *Cryptosporidium* oocyst-sized particle removal.
 - 0.5 log virus removal.

Appendix 5: Post-treatment Process (boron removal) of Seawater Desalination



Appendix 6: Technology Readiness Level (TRL) Definitions



TRL	Description	Remarks
0	Idea	Unproven concept, no testing has been performed
1	Basic Research	Basic principles postulated and observed but no experimental proof available
2	Applied Research	Concept and application have been formulated
3	Critical Function	First laboratory test completed; proof of concept
4	Concept Validation	Small Scale Prototype built in a laboratory environment, technology validated in laboratory
5	Validation of Integrated System	Component and/or validation in a relevant environment
6	Verification of Integrated System	System model or prototype tested in intended environment close to expected performance
7	Demonstration System	Operating in operational environment at pre-commercial scale
8	System Completed and Qualified	Manufacturing issues solved
9	Full commercial application	Technology available for consumers

ANNEX A: Guidelines for Submission of Proposal on IGMS

Closing Date: 24 February 2020, 4:00 pm (Singapore time, GMT +08:00).

1. The preparation of the proposal should be done using the ‘CRP (Water) Research Proposal Form’ which can be downloaded from the online IGMS. The proposal should be submitted in MS Word document or Adobe PDF format, 12-point font size, single-spaced, and the details of proposal should not be longer than 15 full pages.
2. Applicants are required to lodge the application via the online IGMS before the stipulated closing date and time for the Request-for-Proposal (RFP). Separate submission outside of IGMS will not be considered. All relevant sections of the IGMS proposal online application form should be filled out completely, with the CRP (Water) Research Proposal Form and supporting documents uploaded as separate attachments. **The on-line application process may take time and hence please refer to IGMS website for full details of the application process. For new IGMS user from private companies, account registration is required for first time application. Please refer to Annex C below. New users would need to ensure his/her CorpPass account has been set-up, using his/her SingPass account.**
3. For submission of the proposal, it is not necessary for all Co-PIs and collaborators to sign up for an IGMS UserID; only the Lead PI submitting the application needs to do so. The Co-PIs and collaborators may simply be listed as part of the research team in the proposal itself.
4. Please note that applicants can only submit multiple files with maximum file size of 2MB each in the IGMS.
5. Should there be revisions to the submitted proposal, Lead PI is to delete previous submission(s) and only keep the final proposal in the system. Failing to do so may lead to evaluation of wrong version of the proposal.
6. The link to the online IGMS is given here: <https://researchgrant.gov.sg>

ANNEX B: IGMS Account Creation

To facilitate the company accounts' creation, kindly provide the following to Ms. Nur Azimah SALLEH (pub_globalhyrohub@pub.gov.sg) by **27 Dec 2019** to facilitate the registration process.

Details of the New Company to be Created in IGMS

S/N	Full Name of Company	Local Company / Foreign Company?	Public Company / Private Company?	UEN (for Local Company) / Unique Identifier (for Foreign Company)
1				
2				

+++++

Procedures to create a new company account in IGMS:

Once the **new** company account is created in IGMS, the company will need to follow up on registration of the Host Institution (**HI Admin**) in IGMS.

Creation of Users for “Local” Companies

For new “Local” companies, the following steps will need to be done at the company:

- (1) The company will need to nominate a **HI Admin**.
- (2) The **HI Admin** will need to ensure that his/her **CorpPass** account has been setup.
- (3) The **HI Admin** will need to login to IGMS using his/her **CorpPass** account to **register/update** his/her profile inside IGMS. Please note that the IGMS would grant him/her the **Principal Investigator (PI)** role by default.
- (4) After the **HI Admin** has been successfully registered in IGMS, the following details will need to be provided so that IGMS can change the role of the person from a **Principal Investigator (PI)** to a **HI Admin**:
 - **Full Name of HI Admin:**
 - **E-mail Address of HI Admin:**
 - **Designation of HI Admin in his/her company:**
- (5) Once granted the role as a **HI Admin**, he/she can proceed to assign the relevant roles (i.e. Principal Investigator “**PI**”, Director of Research “**DOR**”, Office of Research “**ORE**”) to the various users within his/her organisation.
- (6) The system requires 3 different roles i.e. **PI**, **DOR**, and **ORE** for proposal submission. **HI Admin** and **PI** can be held by the same person, while **DOR** and **ORE** have to be held by 2 different people. As such, there are minimum 3 different personnel required for proposal submission in **IGMS**.

Creation of Users for “Foreign” Companies

For new “Foreign” companies, the following steps will need to be done at the company:

- (1) All users from the company (i.e. **HI Admin, DOR, ORE, PI**) will “**Register**” themselves in IGMS, with reference to the bottom of the “**Login for overseas users without CorpPass/SingPass**” section.
- (2) After all the users have been successfully registered in IGMS, the **HI Admin** will need to provide the information below so that IGMS can **add** all the users, **tag** them to their foreign company, and **assign** the correct roles to all the users inside IGMS:
 - a. Full Name of **HI Admin**:
 - b. E-mail Address of **HI Admin**:
 - c. Designation of **HI Admin** in his/her company:
 - d. Full Name of **DOR**:
 - e. E-mail Address of **DOR**:
 - f. Designation of **DOR** in his/her company:
 - g. Full Name of **ORE**:
 - h. E-mail Address of **ORE**:
 - i. Full Name of **PI/s**:
 - j. E-mail Address of **PI/s**:
- (3) The system requires 3 different roles i.e. **PI, DOR, and ORE** for proposal submission. **HI Admin** and **PI** can be held by the same person, while **DOR** and **ORE** have to be held by 2 different people. As such, there are minimum 3 different personnel required for proposal submission in **IGMS**.
- (4) Once the above **Foreign Company users** have been added, tagged and assigned in IGMS, they can then proceed to login to IGMS via the “**Login for overseas users without CorpPass/SingPass**” section.
- (5) **Note:** The **HI Admin** in the foreign companies cannot add a new user. However, the **HI Admin** in the foreign companies can change the role of a user, or, delete an existing user in his/her company.

ANNEX C: Format for CVs

All CVs submitted for RFP applications must not exceed 2 pages and should use the following format (in terms of sections required and the order of the sections), to highlight key information relevant for the evaluation of proposal:

A. EDUCATIONAL QUALIFICATIONS

B. PROFESSIONAL EXPERIENCE

C. SELECTED PUBLICATIONS MOST CLOSELY RELATED TO THE PROPOSAL

D. SELECTED OTHER PUBLICATIONS (THAT THE REVIEW PANELS SHOULD NOTE)

E. PREVIOUS AND CURRENT RESEARCH GRANTS IN RELATED AREAS

F. LIST OF RECENT COLLABORATORS

G. LIST OF ADVISEES (INCLUDING STUDENTS MENTORED)

H. GRADUATE ADVISORS

ANNEX D: Details of Non-Fundable Direct Cost for CRP (Water) Project

The details of the costs that are non-fundable under CRP (Water) are as follow:

1. EOM Related Expenses

Type of Expenses	Description
General Policy	<p>The general principle is that grants should support EOM costs and related benefits (as per employment contract) as long as it is in line with the consistently applied Host Institution's HR policies.</p> <p>This will extend to Host Institution policies that govern staff recruitment and related costs (e.g. costs associated with the onboarding of staff, staff insurance, overtime claims, staff relocation, employment benefits, employment levy, employment pass, pre-examination medical check-up and housing allowance.)</p> <p>All Manpower related costs that fall under Other Operating Costs (OOE) should be accurately reflected in the Budget.</p> <p>Fractional charging for staff costs based on time commitment to the project must be practised.</p>
PI's, Co-PI's & Co-Investigators' EOM cost	Not allowable.
Unconsumed Leave	Provision for unconsumed leave is not allowable.
Student Assistants / Interns	<p>Not allowable for students who are recipients of existing awards (or stipends) or students who are not residents of Singapore.</p> <p>Only full-time students enrolled in local institutes of higher learning qualify to be supported as a student assistant/intern.</p>

2. Equipment Related Expenses

Type of Expenses	Description
General Policy	<p>No purchase of equipment is allowed unless specifically provided for in the grant and approved by PUB.</p> <p>The procurement of such equipment must be made according to the formal established and consistently applied policies of the Host Institution.</p> <p>The invoices for all claims must be dated before the end of the project completion date.</p>

Type of Expenses	Description
Cost of capital works, general infrastructure, general purpose IT and communication equipment, office equipment, and furniture and fittings	<p>Not allowable under direct costs, unless specifically provided for in the grant and approved by PUB.</p> <p>Examples of such costs are computers, office productivity software, PDAs, mobile phones, photocopier machines, workstations, printers, etc.</p>

3. OOE Related Expenses

Type of Expenses	Description
General Policy	<p>Not allowable for expenses that are <u>not directly related</u> to the research.</p> <p>All procurement of such items must be made according to the formal established and consistently applied policies of the Host Institution.</p>
Visiting Professors/Experts	Not allowable unless specifically provided for in the grant and approved by PUB. The visiting professor must be identified and his/her contribution to the project must be clearly defined and described in the proposal.
Audit Fees	Not allowable. This includes both internal and external audit fees.
Entertainment & Refreshment	Not allowable.
Fines and Penalties	Not allowable.
Legal Fees	Not allowable.
Overhead Expenses	Not allowable unless specifically provided for in the grant and approved by PUB based on the nature of the research. This includes rental, utilities, facilities management, telephone charges, internet charges, etc.
Patent application	<p>Not allowable.</p> <p>This includes patent application filing, maintenance and other related cost.</p>
Professional Membership Fees	Not allowable. This applies to PI and Co-Investigators as well as all research staff funded from the grant.
Software	Not allowable under direct cost unless specifically provided for in the grant and approved by PUB.
Professional fees (including fees to consultants)	Not allowable unless specifically provided for in the grant and approved by PUB.
Staff Retreat	Not allowable.

4. OOE – Overseas Travel Related Expenses

Type of Expenses	Description
General Policy	<p>Not allowable unless specifically provided for in the grant and approved by PUB.</p> <p>Conference participation should be directly relevant to the research area outlined in the project and necessary to accomplish project objectives.</p> <p>All travel must align to the existing and consistently applied institutions' travel policies regardless of the source of funds.</p>

5. Research Scholarship

Type of Expenses	Description
General Policy	<p>Not allowable unless specifically provided for in the grant and approved by PUB.</p> <p>Postgraduate stipend must align with the prevailing rates set by the Ministry of Education. Postgraduate stipend and tuition support will not attract indirect costs.</p>
Undergraduate stipend and tuition support	Not allowable.

ANNEX E: Endorsement by Host Institution / Organisation

I declare that the contents described in the Preliminary Proposal are true, and that the Organisation is free from any litigation pertaining to the project in Singapore or overseas.

PROJECT TITLE: _____

Signature of Principal Investigator (PI):	Organisation:
Name (in BLOCK LETTERS):	Contact Number:
PI's Designation:	E-mail Address:

Supported by Head of Department or equivalent position holder in the Organisation

Signature:	Designation:
Name (in BLOCK LETTERS):	Date (DD/MM/YY)

Supported by Dean, Chair of Faculty or equivalent position holder in the Organisation

Signature:	Designation:
Name (in BLOCK LETTERS):	Date (DD/MM/YY)

Endorsement by Organisation (Research Director, CEO, MD or equivalent)

Signature:	Stamp of Organisation
Name (in BLOCK LETTERS)/ Designation:	Date (DD/MM/YY)