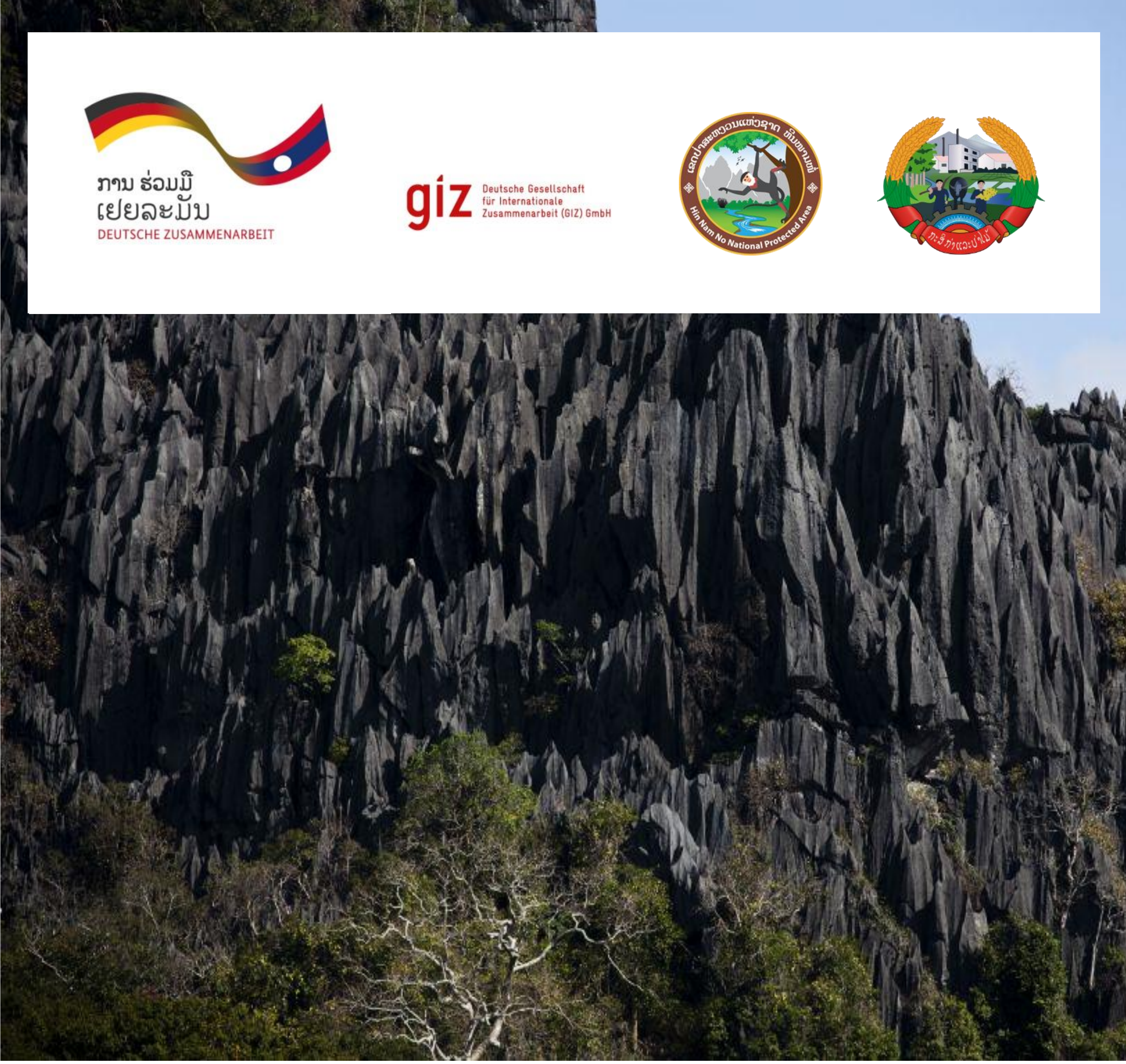

Preparing the Groundwork for the Geoheritage Aspects of a World Heritage Nomination for Hin Nam No NPA

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Contribution of the contractor, Terry Bolger, do not necessarily represent the position of GIZ.

On behalf of the
German Federal Ministry for Economic Cooperation and Development (BMZ)

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Preparing the Groundwork for the Geoheritage Aspects of a World Heritage Nomination for Hin Nam No NPA – Executive Summary

Hin Nam No NPA and Phong Nha Ke Bang NP are located within the Central Indochina Limestone, which is one of the largest karst regions in Southeast Asia. This region is also commonly referred to as the Khammouane Limestone, and forms a belt of karst 290 km long and 30 km to 120 km wide stretching across central Lao PDR and into Vietnam. The 1100 m thick main carbonate sequence is middle Carboniferous to early Permian.

This initial comparative analysis shows that HNN has many of the same geoheritage features as those recognized as being of OUV for PNKB as both parks belong to the same large dissected karst plateau. Among these are: Dissected plateau with polygonal cone karst, extensive closed or border depressions (polje), planation surfaces recognized at several levels, some of the world's largest caves and underground rivers (Soon Dong cave/Xe Bang Fai cave), changes in routes of underground rivers, cave passages at different levels (fossil), giant speleothems (deposition).

Many of these features for HNN are at least as "good" as, or add value to, the features of OUV for PNKB. Whether any of the similar OUV features are "better" in HNN could not be determined from this desk study and still needs to be assessed by the geoheritage/Karst WH expert. The similarity of geoheritage features between HNN and PNKB is important for making the case for HNN as a transboundary extension to the PNKB World Heritage site.

This comparative analysis only identifies two features in HNN that differ or are not present in PNKB. One is the 'signature' karst pinnacles in HNN. The other is that the HNN karst landscape may be more mature than that of PNKB. Finally, the topographic relationship of non-karst landforms elevated above the limestone karst is recognized as being an important feature controlling the karst landscape evolution in both HNN and PNKB. Whether any of these features represent or contribute to OUV will need to be assessed by the geoheritage /Karst WH expert.

On the other hand, there are several OUV features in PNKB that do not appear to be present in HNN. These include: Interbedding of shale and sandstone, capping of schists and granite, and at least one period of hydrothermal activity, which are said to have led to the distinctive geomorphology of the landforms and caves of PNKB. If these features are confirmed not to occur in HNN, then the morphology of the landforms and caves of HNN may be expected to differ from those of PNKB. Again, this will need to be assessed by the geoheritage/Karst WH expert.

This comparative analysis also highlights the lack of knowledge about the stratigraphy, landform geomorphology, and landscape evolution of HNN (and PNKB as well). Scientific studies and expert assessments to fill these knowledge gaps are needed to develop the justification of OUV for the geoheritage of HNN.

It is generally presumed that the underground drainage systems of the HNN karst flow into the Xe Bang Fai or Nam Ngo rivers. However, it is possible that some of the underground drainage of the HNN karst flows to the karst of PNKB in Vietnam, and vice-versa. Nevertheless, there is also a lack of knowledge about the hydrology and water quality, of the Xe Bang Fai river especially, which is needed to develop the protection and management, and monitoring requirements for the OUVs.

Finally, one of the key differences between PNKB and HNN is the climate on the two sides of the border. On the Vietnam side, the prevailing climate is generally moist throughout the year as a result of the influences of the South China Sea and the Truong Son Range, which forms an important divide between the PNKB and HNN portions of the karst plateau. In comparison, HNN has a tropical, monsoonal climate with a distinct wet season and a long, hot, dry season. The wet season is from June through October. The dry season (November-May) in HNN is longer and drier than in PNKB. These differences in climate have influenced the vegetation and possibly the geomorphology of the two properties.

ການກະກຽມຂໍ້ມູນພື້ນຖານທາງດ້ານມໍລະດົກທໍລະນີສັນຖານວິທະຍາສໍາລັບການສະເໜີຊື່ເອົາປ່າສະຫງວນແຫ່ງຊາດຫີນໜາມໜໍ່ເຂົ້າເປັນມໍລະດົກໂລກ.
ບົດສະຫຼຸບຫຍໍ້

ປ່າສະຫງວນແຫ່ງຊາດຫີນໜາມໜໍ່ ແລະ ອຸທິຍານແຫ່ງຊາດຟອງຍາແກ່ບ່າງຕັ້ງຢູ່ໃນທາງພາກກາງຂອງພູຫີນປູນອິນດູຈີນ ເຊິ່ງເປັນຂົງເຂດພູຫີນປູນທີ່ກວ້າງໃຫ່ຍແຫ່ງໜຶ່ງໃນອາຊີຕາເວັນອອກສ່ຽງໃຕ້. ຂົງເຂດນີ້ເອີ້ນວ່າພູຫີນປູນຄໍາມ່ວນ ແລະ ກໍາເນີດເປັນພູຫີນປູນທີ່ມີຄວາມຍາວ 290 ກິໂລແມັດ ແລະ ຄວາມກ້ວາງ 30 ຫາ 120 ກິໂລແມັດຍາວຢຽດຕາມທາງພາກກາງຂອງ ສປປ ລາວ ແລະ ໄປຮອດປະເທດຫວຽດນາມ. ລໍາດັບຂອງທາດຄາບອນຂະໜາດໃຫ່ຍທີ່ມີຄວາມໜາ 1100 ແມັດຢູ່ໃນໄລຍະກາງຂອງຍຸກຖ່ານຫີນ (ຍຸກຄາຣບອນນິເຟີຣັສ) ຫາ ໄຍລະຕົ້ນຂອງຍຸກທີ່ເລີ່ມມີສັດເລືອຄານ (ຕົ້ນຍຸກເພີມຽນ)

ການວິເຄາະສົມທຽບເບື້ອງຕົ້ນນີ້ສະແດງໃຫ້ເຫັນວ່າຫີນໜາມໜໍ່ມີລັກສະນະທາງດ້ານມໍລະດົກທໍລະນີສັນຖານວິທະຍາທີ່ຄືກັນຫຼາຍຢ່າງ ກັບ ຄຸ່ນຄ່າຄວາມເປັນເອກະລັກສະເພາະທີ່ໂດດເດັ່ນຂອງຂອງທີ່ຮັບຮູ້ກັນໃນອຸທິຍານແຫ່ງຊາດຟອງຍາແກ່ງບ່າງ ເນື່ອງຈາກວ່າທັງສອງພື້ນທີ່ນີ້ເປັນພູພຽງຫີນປູນຂະໜາດໃຫ່ຍອັນດຽວກັນ ບັນດາສິ່ງທີ່ຄືກັນໄດ້ແກ່: ພູພຽງຫີນປູນເຕັມໄປດວ້ຍຫີນປູນທີ່ມີຮູບຮ່າງແຫຼມຄ້າຍຄືກັບຈວຍ, ເປັນອ່າງທີ່ເປີດກວ້າງ ຫຼື ອ່າງເຂດແດນທີ່ຕໍ່າ (ພື້ທີ່ພຽງນໍ້າຖວ້ມຂະໜາດໃຫ່ຍຢູ່ເຂດພູຫີນປູນ),ພື້ນທີ່ຂະໜາດຮາບພຽງຂະໜາດໃຫ່ຍທີ່ມີເນີນພູຫີນປູນໄດ້ມີການຮັບຮອງໃນຫຼາຍລະດັບ, ມີຖໍ້າ ແລະ ແມ່ນໍ້າໄຫຼລອດພື້ນດິນຂະໜາດໃຫ່ຍລະດັບໂລກບາງແຫ່ງ (ຖໍ້າເຊີນດົງ/ຖໍ້ານໍ້າລອດເຊບັ້ງໄຟ), ການປ່ຽນແປງເສັ້ນທາງໄຫຼຂອງນໍ້າໃຕ້ດິນ, ອຸໂມງຖໍ້າມີຫຼາຍລະດັບແຕກຕ່າງກັນ (ຊາກພືດຫຼືສັດທີ່ກາຍເປັນຫີນ), ລັກສະນະຂອງຫີນທີ່ເກີດພາຍໃນຖໍ້າຂະໜາດໃຫ່ຍ (ການທັບຖົມ)

ບັນດາລັກສະນະເຫຼົ່ານີ້ໃນຫີນໜາມໜໍ່ຢ່າງໜ້ອຍຖືວ່າ “ດີ” ຫຼື ເພີ່ມຄຸນຄ່າຄືກັນກັບລັກສະນະໂດດເດັ່ນສໍາລັບຄຸ່ນຄ່າຄວາມເປັນເອກະລັກທີ່ໂດດເດັ່ນຂອງໂລກຂອງຟອງຍາແກ່ບາງ. ບໍ່ວ່າລັກສະນະຂອງຄຸນຄ່າຄວາມເປັນເອກະລັກທີ່ໂດດເດັ່ນຂອງໂລກທີ່ຄ້າຍຄືກັນໃນປ່ສະຫງວນແຫ່ງຊາດຫີນໜາມໜໍ່ຖືກວ່າ “ດີກວ່າ” ເຊິ່ງອາດຈະບໍ່ສາມາດກໍານົດໄດ້ຈາການສຶກສາເອກະສານນີ້ ແລະ ມັນຍັງຈໍາເປັນຕ້ອງໄດ້ມີການປະເມີນໂດຍຊ່ຽວຊານມໍລະດົກທາງດ້ານທໍລະນີສັນຖານວິທະຍາ/ມໍລະດົກໂລກທາງດ້ານພູຫີນປູນ.
ຄວາມຄ້າຍຄືກັນຂອງລັກສະນະທາງດ້ານມໍລະດົກທໍລະນີສັນຖານລະຫວ່າງຫີນໜາມໜໍ່ ກັບ ອຸທິຍານແຫ່ງຊາດຟອງຍາແກບ່າງມີຄວາມສໍາລັບສໍາລັບໃນການເຮັດໃຫ້ຫີນໜາມໜໍ່ເປັນພື້ນທີ່ມໍລະດົກໂລກຮ່ວມຊາຍແດນຕໍ່ອອກຈາກພື້ນທີ່ມໍລະດົກໂລກຂອງຟອງຍາແກບ່າງ.
ການວິເຄາະສົມທຽບນີ້ກໍານົດພຽງແຕ່ສອງລັກສະນະໃນຫີນໜາມໜໍ່ວ່າແຕກຕ່າງກັບຟອງຍາແກບ່າງ ຫຼື ບໍ່ມີຢູ່ລັກສະນທີ່ບໍ່ມີຢູ່ໃນຟອງຍາແກ່ບາງ. ລັກສະນະໜຶ່ງແມ່ນລັກສະນະພູຫີນປູນແຫຼມຄົມທີ່ເປັນ “ເອກະລັກ” ໃນຫີນໜາມໜໍ່ ແລະ ລັກສະນະທີ່ສອງແມ່ນທິວທັດຂອງພູຫີນປູນຂອງຫີນໜາມໜໍ່ອາດຈະມີຄວາມສົມບູນຫຼາຍກວ່າຟອງຍາແກບ່າງ. ສະຫຼຸບແລ້ວ, ຄວາມສໍາພັນທາງດ້ານພູມມີສາດຂອງການກໍາເນີດຂອງດິນທີ່ບໍ່ແມ່ນພູຫີນປູນທີ່ໄດ້ຍົກຂຶ້ນເທິ່ງພູຫີນປູນນັ້ນແມ່ນຖືວ່າເປັນລັກສະນະທີ່ສໍາຄັນໃນການຄວບຄຸມວິວັດທະນາການຂອງພື້ນທີ່ພູຫີນປູນໃນຫີນໜາມໜໍ່ ແລະ ຟອງຍາແກບ່າງ ບໍ່ວ່າບັນດາລັກສະນະເຫຼົ່ານີ້ສະແດງເຖິງ ຫຼື ປະກອບສ່ວນໃຫ້ກັບຄຸ່ນຄ່າຄວາມເປັນເອກະລັກສະເພາະທີ່ໂດດເດັ່ນຂອງໂລກກໍ່ຕາມ ມັນຍັງຈໍາເປັນຈະຕ້ອງໄດ້ມີການປະເມີນໂດຍຊ່ຽວຊານມໍລະດົກທໍລະນີສັນຖານວິທະຍາ/ຊ່ຽວຊານມໍລະໂດກໂລກພູຫີນປູນ.

ເຖິງແນວໃດກໍ່ຕາມ, ອຸທິຍານແຫ່ງຊາດຟອງຍາແກປ່າງມີລັກສະນະດ້ານຄຸນຄ່າຄວາມເປັນເອກະລັກທີ່ໂດດເດັ່ນຂອງໂລກຫຼາຍຢ່າງທີ່ບໍ່ມີໃນປ່າສະຫງວນແຫ່ງຊາດຫີນໜາມໜໍ່ ເຊິ່ງບັນດາລັກສະນະນີ້ປະກອບມີ: ລັກສະນະບັນດາຊັ້ນຫີນຂອງຫີນດິນດານ ແລະ ຫີນຊາຍ, ຊັ້ນຫີນທີ່ປະກອບມີແຮ່ທາດຕ່າງໆ ແລະ ຫີນແກນິດຢ່າງໜ້ອຍຢູ່ໃນຍຸກໜຶ່ງຂອງການລະເບີດຂອງບໍ່ນໍ້າຮອ້ນ ເຊິ່ງກ່າວກັນວ່າໄດ້ເຮັດໃຫ້ມີລັກສະນະທໍລະນີສັນຖານທີ່ແຕກຕ່າງກັນຢ່າງໂດດເດັ່ນກ່ຽວກັບການກໍາເນີດຂອງດິນ ແລະ ຖໍ້າໃນອຸທິຍານແຫ່ງຊາດຟອງຍາແກປ່າງ. ຖ້າຫາກວ່າບັນດາລັກສະນະເຫຼົ່ານີ້ໄດ້ຖືກຢັ້ງຢືນວ່າບໍ່ມີໃນຫີນໜາມໜໍ່ ກໍ່ອາດຄາດຈະວ່າພູມສັນຖານກ່ຽວກັບການກໍາເນີດຂອງດິນ ແລະ ຖໍ້າໃນຫີນໜາມໜໍ່ແຕກຕ່າງຈາກອຸທິຍານແຫ່ງຊາດຟອງຍາແກ່ປ່າງ. ນອກຈາກນີ້ ເລື່ອງນີ້ຈະຈໍາເປັນຕ້ອງມີການປະເມີນໂດຍຊ່ຽວຊານມໍລະດົກທໍລະນີສັນຖານ/ມໍລະດົກໂລກທາງດ້ານພູຫີນປູນ.

ການວິເຄາະສົມທຽບນີ້ກໍ່ຍັງຊີ້ໃຫ້ເຫັນເຖິງຄວາມຂາດແຄນທາງດ້ານຄວາມຮູ້ວິຊາການທໍລະນີວິທະຍາກ່ຽວກັບລໍາດັບຂອງຊັ້ນຫີນ, ທໍລະນີສັນຖານວິທະຍາກ່ຽວກັບການກໍາເນີດຂອງດິນ ແລະ ວິວັດທະນາການຂອງພື້ນທີ່ຫີນໜາມໜໍ່ (ແລະ ອຸດທິຍານແຫ່ງຊາດຟອງຍາແກ່ປ່າງ). ດັ່ງນັ້ນຈໍາເປັນຕ້ອງມີການສຶກສາທາງດ້ານວິທະຍາສາດ ແລະ ການປະເມີນຂອງບັນຊ່ຽວຊານເພື່ອໃຫ້ມີຂໍ້ມູນຂອງຄວາມຮູ້ດ້ານວິຊາການທີ່ຍັງຂາດ ເພື່ອທີ່ຈະເປັນຫຼັກຖານອ້າງອີງໃນການອະທິບາຍເຖິງຄຸນຄ່າຄວາມເປັນເອກະລັກສະເພາະທີ່ໂດດເດັ່ນຂອງໂລກສໍາລັບມໍລະດົກທາງດ້ານທໍລະນີສັນຖານວິທະຍາຂອງຫີນໜາມໜໍ່.

ໂດຍທົ່ວໄປແລ້ວ ສັນນິຖານວ່າ ລະບົບການລະບາຍນໍ້າໃຕ້ດິນຂອງພູຫີນປູນຫີນໜາມໜໍ່ນັ້ນໄຫຼເຂົ້າໂຮມເຂົ້າສູ່ແມ່ນໍ້າເຊບັ້ງໄຟ ຫຼື ແມ່ນໍ້າໂງ່. ເຖິງແນວໃດກໍ່ຕາມ ອາດຈະເປັນໄປໄດ້ການລະບາຍນໍ້າໃຕ້ດິນໃນພູຫີນປູນຫີນໜາມໜໍ່ຈະໄຫຼໄປສູ່ພູຫີນປູນອຸທິຍານແຫ່ງຊາດຟອງຍ່າແກປ່າງໃນປະເທດຫວຽດນາມ ແລະ ໃນທາງກັບກັນອີກດວ້ຍ. ຢ່າງໃດກໍ່ຕາມ ກໍ່ຍັງມີຂາດຄວາມຮູ້ທາງດ້ານວິຊາການກ່ຽວກັບອຸທົກວິທະຍາ ແລະ ຄຸນນະພາບນໍ້າ ໂດຍສະເພາະແມ່ນ ແມ່ນໍ້າເຊບັ້ງໄຟ ເຊິ່ງຈໍາເປັນຕ້ອງໄດ້ມີການສ້າງຂໍ້ກໍານົດທີ່ຈໍາເປັນສໍາລັບການປົກປັກຮັກສາ, ການຄຸ້ມຄອງ ແລະ ການຕິດຕາມບັນດາຄຸນຄ່າຄວາມເປັນເອກະລັກສະເພາະທີ່ໂດດເດັ່ນຂອງໂລກໄວ້.
ສະຫຼຸບແລ້ວ ຄວາມແຕກຕ່າງທີ່ສໍາຄັນຢ່າງໜຶ່ງລະຫວ່າງປ່າສະຫງວນແຫ່ງຊາດຫີນໜາມໜໍ່ ກັບ ອຸທິຍານແຫ່ງຊາດຟອງຍາແກປ່າງແມ່ນ ສະພາບອາກາດໃນທັງສອງຊາຍແດນຂອງປະເທດ. ໃນເບື້ອງຊາຍແດນຫວຽດນາມ ສະພາບອາດກາດທີ່ຢູ່ທົ່ວໄປສ່ວນໃຫ່ຍແມ່ນອາກາດຊຶ່ມຕະຫຼອດປີເປັນສາເຫດມາຈາກອິດທິພົນຂອງທະເລຈີນໃຕ້ ແລະ ສາຍພູເຈື່ອງເຊີນ ເຊິ່ງກໍ່ໃຫ້ເກີດມີການແບ່ງເຂດສະພາບອາດກາດທີ່ສໍາຄັນລະຫວ່າງພູພຽງຫີນປູນອຸທິຍານແຫ່ງຊາດຟອງຍາແກປ່າງ ກັບ ຫີນໜາມໜໍ່. ໃນການສົມທຽບ, ຫີນໜາມໜໍ່ມີສະພາບອາກາດແບບຮ້ອນຊຸ່ມ ແລະ ລົມມໍລະສຸມທີ່ມີລະດູຝົນທີ່ແຕກຕ່າງກັນ ແລະ ລະດູແລ້ງທີ່ຮ້ອນຍາວ. ໃນຫີນໜາມໜໍ່ ລະດູຝົນແມ່ນເລີມຈາກເດືອນ ມິຖຸນາ ຈົນເຖິງ ເດືອນ ຕຸລາ, ລະດູແລ້ງ (ເດືອນພະຈິກ-ເດືອນ ພຶດສະພາ) ແມ່ນດົນ ແລະ ແຫ້ງແລ້ງກວ່າສະພາບອາກາດໃນອຸທິຍານແຫ່ງຊາດຟອງຍາແກປ່າງ. ບັນດາຄວາມແຕກຕ່າງດ້ານສະພາບອາກາດນີ້ໄດ້ສົ່ງອິທິພົນຕໍ່ກັບພືດພັນ ແລະ ອາດຈະເປັນລັກສະນະທາງດ້ານທໍລະນີສັນຖານວິທະຍາຂອງພື້ນທີ່ທັງສອງແຫ່ງອີກດວ້ຍ.

REVIEW OF THE GEOLOGY, GEOMORPHOLOGY AND HYDROLOGY OF HIN NAM NO

REGIONAL SETTING

The Central Indochina Limestone is one of the largest karst regions in Southeast Asia. This region is also commonly referred to as the Khammouane Limestone, and forms a belt of karst 290 kilometres (km) long and 30 km to 120 km wide stretching across central Lao PDR and into Vietnam (Figure 1). In Lao PDR, the limestone is mainly an arcuate, NW to SE tending faulted anticlinorium, following the Thakhek fault at its southern boundary. The 1100 m thick main carbonate sequence is middle Carboniferous to early Permian, consisting of limestones, dolomitic limestones, and dolomites [8].

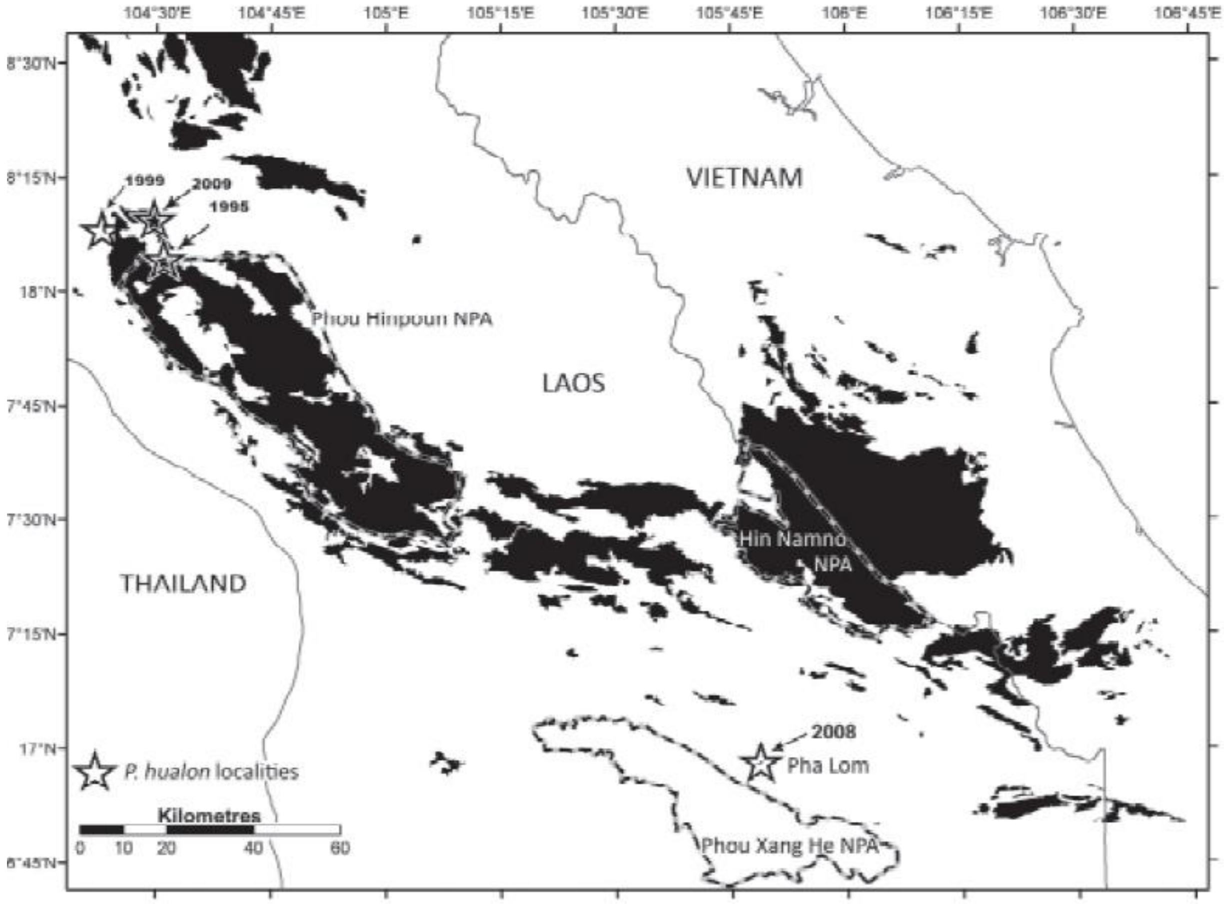

Figure 1. Map with the Central Indochina Limestone region shown in black.

The Hin Nam No National Protected Area (HNN NPA) covers 820 km^2 of mainly limestone landscape in Khammouane Province in central Laos, where the Central Indochina Limestone meets the Annamite Mountain Chain (Figure 2). HNN is part of a large, dissected karst plateau which continues across the border into Vietnam where a large portion (1233 km^2) of the contiguous Phong Nha Ke Bang (PNKB) karst has been designated as a national park and World Heritage (WH) site.

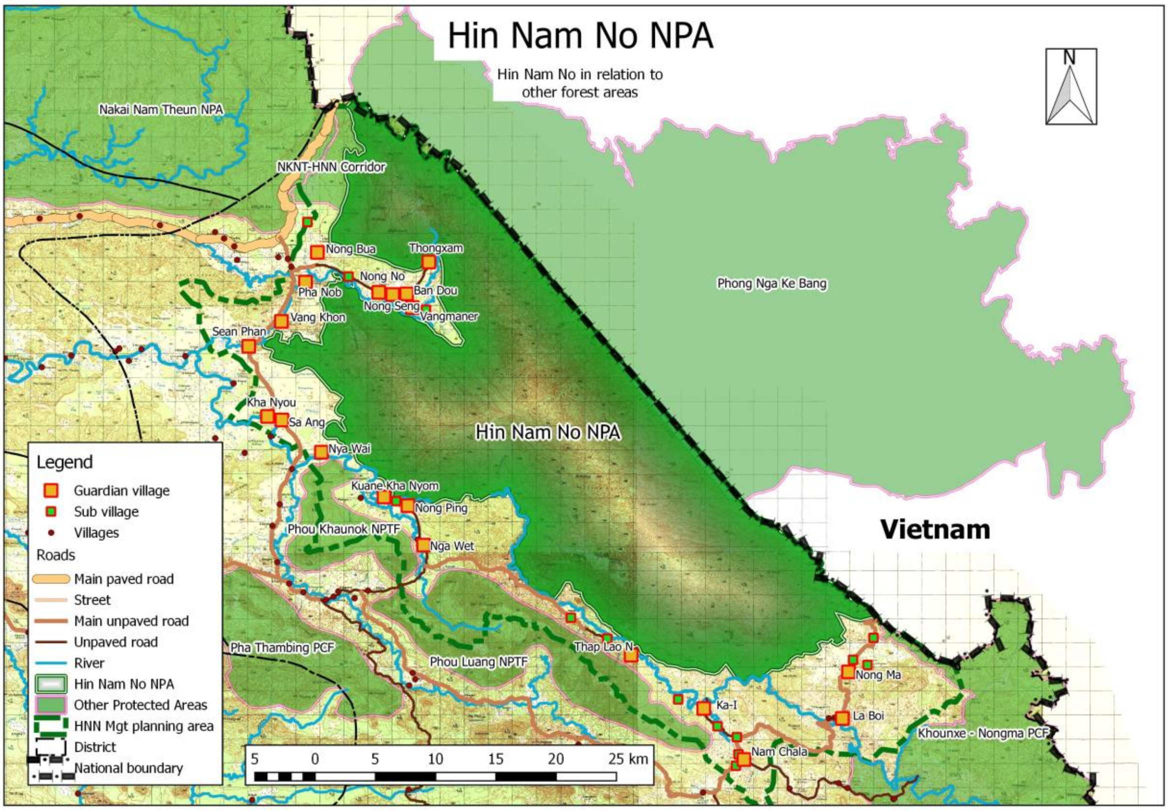

Figure 2. Map with Hin Nam No in relation to Phong Nha Ke Bang and other protected areas.

LITHOLOGY AND STRATIGRAPHY

The karst plateau comprises greater than 90% of the area of HNN. The karst of HNN is formed in the middle Carboniferous to early Permian Khammouane Formation, which is massive and up to 1100 m thick. It is comprised of carbonate rocks of limestone, dolomitic limestone or dolomite lithology, which are hard, compact and pure. The Khammouane Formation is underlain by the sandstones of the early Carboniferous Boualapha Formation [8, 10].

During the Mesozoic Era the Khammouane Formation was covered unconformably by continental red beds of the early to middle Jurassic Ban Lao Formation, which in turn was covered by the red beds of the late Jurassic Nam Phouan and early Cretaceous Nam Xot Formations. The stratigraphic gap of the unconformity between the Paleozoic carbonates and Mesozoic red beds reaches up to 60 million years in central Laos. This gap in the sedimentary record indicates a long erosion period favorable to karst formation, before burial by the Mesozoic continental red beds created a paleokarst [6, 10].

GEOLOGIC STRUCTURE

The geological structure of HNN is dominated by the Truong Son anticlinorium extending NW-SE. It was formed during the late Devonian to early Carboniferous, and reactivated during the Cenozoic to the present. The fault systems in HNN have not been studied in any detail, but geologic maps of the area indicate primary faults trending NW-SE, and NE-SW trending secondary faults [8, 10, 11].

KARST LANDSCAPE EVOLUTION

Morphogenetic evolution of the karst is the result of a complex tectonic history. The Indosinian orogeny occurred in the middle Triassic (247 Ma). This significant compression, uplift, and erosion episode affected much of Southeast Asia, bringing many carbonates into subaerial positions, and resulting in a prolonged karstification episode of up to 40 million years in central Laos. The karst was subsequently buried (paleokarst) under thick layers of Jurassic and early Cretaceous sandstones and shales. A new uplift began in the Paleogene (65 Ma), leading to large scale erosion. This erosion stripped off 2700 m or more of the covering sandstones and shales in parts of Khammouane. As the limestone became progressively re-exposed karst evolution resumed in earnest. Triassic karst landforms have been exhumed and rejuvenated and play a significant role in the evolution of the modern karst. Where the karst relief is large enough, the modern karst has likely cut through the Triassic karst [6].

While the evidence for paleokarst in central Laos has been documented by Mouret [6], few paleokarst features have been documented in HNN itself. A karst breccia paleo-cavity fill has been observed in one of the upper-level side passages of the Xe Bang Fai cave. Karst pinnacles occurring at the contact between the limestone and the sandstone on the northern flank of Phou Chuang mountain may also provide evidence of the paleokarst. More paleokarst features in HNN need to be identified and documented.

Neotectonic uplift and faulting during the Cenozoic has influenced the formation and rejuvenation of the modern karst landscapes of HNN. Due to the effects of rejuvenation, the karst at HNN now appears to represent an early stage of landscape evolution (plateau with cone karst), despite a long period of landscape evolution and residual, well-developed karst features such as polje. In general, the landscape evolution of HNN has been little studied or assessed. This is a key deficiency that needs to be addressed for developing the justification of OUV for the geoheritage (criterion viii) of HNN.

The regional geomorphology is said to be controlled by three factors [7]:

- A thick silici-clastic cover above the carbonate
- A regional folding with a NW-SE axis
- An inverted surface erosion with eroded anticlines and anticlinoriums and better-preserved synclines, though karst plains can be found along some syncline axes

This sandstone-limestone association is very favorable to karstification. It drains synclines at a high elevation, which is favorable to larger water flows, especially during floods. It provides high velocity to the water due to steep slopes. It also makes the water more acidic and provides abundant abrasive sand, pebbles and cobbles which contribute significantly to cave erosion during the floods [7]. A good example of this in HNN is Nam Ock cave. The cave has been formed by the Houay Hok stream that begins on the high sandstone slopes of Phou Chuang mountain before flowing onto the limestone and sinking underground. Sandstone cobbles and boulders are found through the cave streambed and cemented into flowstone.

KARST LANDFORMS AND FEATURES

The characteristic landscape style of the Hin Nam No karst is that of a dissected plateau of karst massifs that are almost completely bordered by bare limestone walls or cliffs rising up to 500 m above intervening alluvial plains and flat-bottomed basins, known locally as kouans, and as poljes to karst specialists. The limestone massifs have been eroded into a classic fengcong karst of clustered cones, with steep cones and pinnacles together with deep fissures and dolines on the summit surfaces, making them virtually inaccessible [13].

Within or at the margins of the karst plateau in HNN are extensive closed or border depressions with steep walls, known as kouans or poljes. They result from erosion and planation at the wet season water table. Dissolutional planation has worked outwards, forming notches and foot caves that undercut the limestone walls, resulting in collapse and creating precipitous marginal cliffs [13]. Poljes are relatively common in plateau karst either where alluviation has been dominant or where impermeable rocks such as sandstone or shale underlie the limestone [4]. In HNN, at least some of the poljes, such as the large border polje in the north of the property (Ban Dou area), are developed on the breached cores of anticlines where the basement sandstone floors (Boualapha Formation) are exposed [10, 13]. Poljes are a ‘climax’ form, indicating well-developed karst. Karst towers occur around the edges of some poljes in HNN.

Sharp-edged and spectacular pinnacles up to 10 m high [8] are signature features of the karst landscape, from which Hin Nam No derives its name (i.e. spiky rocks in English). Pinnacle karst is a spectacular, small-area landform found mainly in the humid tropics and subtropics. The pinnacles are razor-edged limestone blades, closely packed, which can attain heights up to 50 m [4]. They are typically formed by the fracturing and weathering of hard, pure, massive limestone such as the Khammouane limestone of HNN.

The allogenic water of the Xe Bang Fai river has cut a 6.4 km underground course through the HNN karst, creating one of the largest active river cave passages in the world (Figure 3).

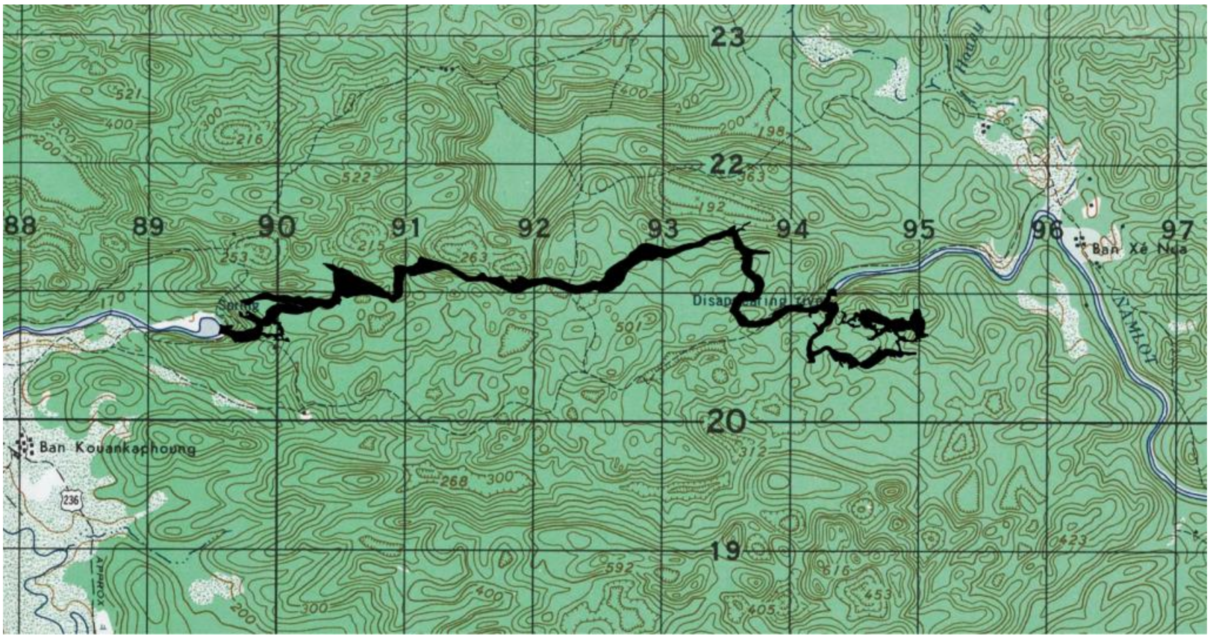

Figure 3. Map of the Xe Bang Fai cave overlaid on a topographic map with a 1 km grid.

The active river passage averages 76 m in width and 53 m in height, with a maximum width of 200 m and a maximum height of 120 m [9]. In addition to the size of the cave passages, the cave is superbly decorated with speleothems, including many large and beautiful stalagmites, flowstone draperies, cave pearls and gour pools, including a 61 m long gour basin considered to be the world's largest single gour pool to have formed in a cave [2].

The total length of the Xe Bang Fai cave system is now 16 km. In addition to the active river passage there are higher level paleo-passages that indicate ancient routes of the underground river, both upstream of the current active river passage, and in the downstream section of the cave. A major finding resulting from the recent exploration and mapping of the caves upstream of the Xe Bang Fai cave is that these caves (Tham Nguen, Tham Nguen Mai, Heup Pha Pong and Tham Pha Pong), along with the Grotte de Nuages section of the Xe Bang Fai cave, appear to comprise an ancient underground route of the Xe Bang Fai river, as illustrated in Figure 4. The large fossil passage between Tham Nguen and Tham Nguen Mai appears to have been destroyed by erosion. Similarly, Heup Pha Pong and Tham Pha Pong appear to have been isolated by erosion. These large, upstream fossil galleries are elevated between 30 m and 50 m above the current active river channel [1].

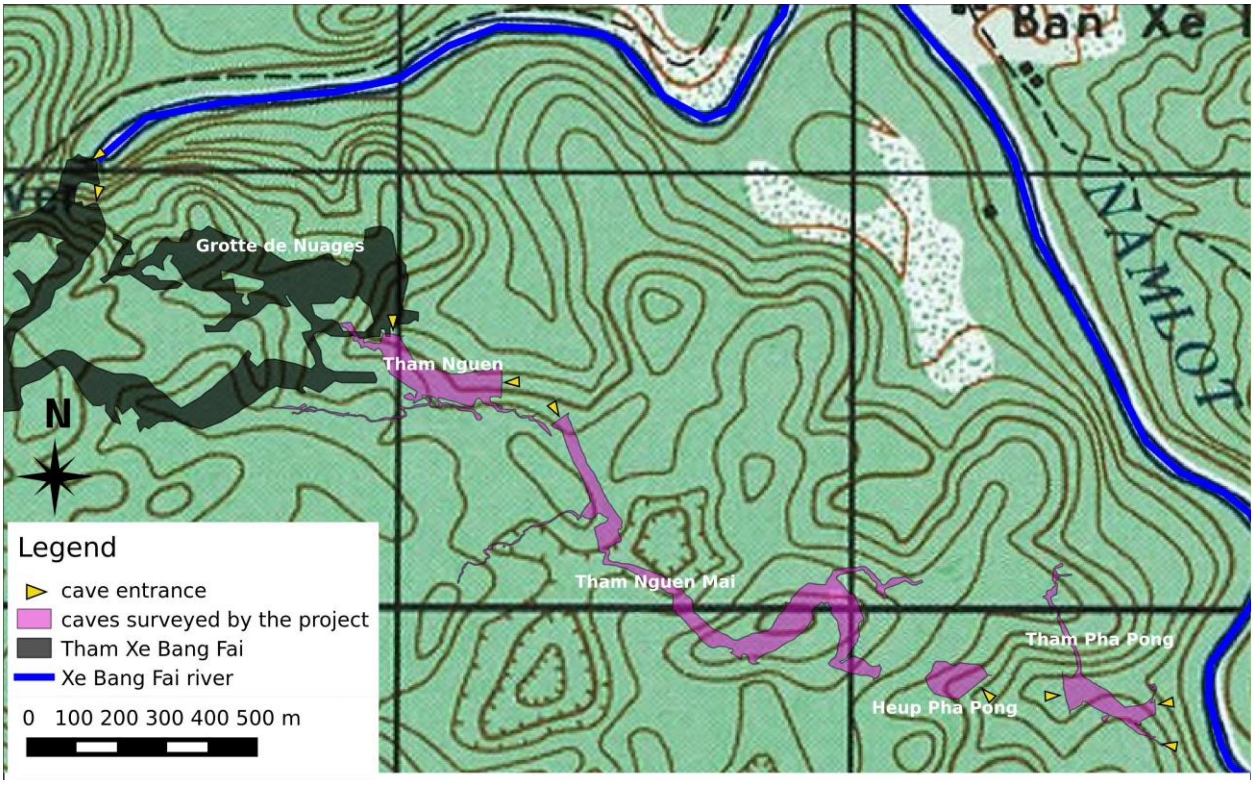

Figure 4. Map of the caves upstream of the Xe Bang Fai cave overlaid on a topographic map with a 1 km grid.

In the downstream section of the Xe Bang Fai cave, the Tham Bing passage is the ancient route of the river, as clearly evidenced by the erosion channel in the cave ceiling at the junction with the active river passage. The floor of the Tham Bing passage is about 50 m above the active river channel. Further downstream, the Balcony passage is a paleo-passage elevated about 18 m above the active river channel.

KARST HYDROLOGY

In HNN, the karst hydrology is comprised of both autogenic and allogenic water sources. There are two river systems that drain the HNN karst. The Nam Ngo is an autogenic river that drains the northern area of HNN (Figure 2). It flows out of the karst southeast of Vangmaner village and across a large border polje (180 m elevation) and then flows into the Xe Bang Fai river (confluence at 160 m elevation) to the west of the property. The Nam Ngo riverbed is generally dry from February through April, reflecting the lack of water storage or retention in the limestone karst. The Houay Hok is a tributary stream that flows out of the mountains north of Thongxam village and drains into the Nam Ngo at Vangmaner village. This stream begins on the sandstone slopes of Phou Chuang mountain before flowing onto the limestone and through three caves. It flows all year but becomes just a trickle by the late dry season.

The Xe Bang Fai is an allogenic river whose headwaters are on non-karstic rocks about 40 km to the south of HNN (Figure 2). It flows from SE-NW along the western edge of the HNN karst before turning west to flow through the Xe Bang Fai cave. Upon exiting the cave and the karst of HNN (170 m elevation) it continues to flow west about 130 km to the Mekong river (confluence at 130 m elevation).

The Xe Bang Fai river has a large catchment area upstream of the cave, of 1310 km^2. Thus, it flows water all year long and is one of the only water sources in HNN during the dry season. A hydrologic gauging station is located on the Xe Bang Fai river at Mahaxai, 60 km downstream from its resurgence from the Xe Bang Fai cave. Thirteen years of discharge data from the Mahaxai station was used to estimate monthly discharge rates at the resurgence of the Xe Bang Fai cave, by taking account of the relative catchment areas and other assumptions made by Mouret et al. [7]. These estimates are presented in Table 1, showing minimum, mean and maximum discharge rates for each month. The discharge rates are lowest during the months of February, March and April (late dry season), and show a distinct peak during the months of July, August and September (wet season). With a mean annual discharge of 72 m^3/sec, this is likely one of the largest cave rivers in the world.

Table 1. Estimated monthly discharge (m^3/sec) from the Xe Bang Fai cave

Monthly	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Minimum	5.2	3.4	2.1	1.9	2.7	27.6	117.9	102.4	76.2	33.2	5.8	4.1
Mean	7.2	5.1	3.9	3.7	11.7	70.8	190.1	267.0	201.1	66.8	30.9	12.1
Maximum	11.8	7.0	7.5	7.1	30.9	157.4	349.5	478.1	420.8	128.0	60.9	17.1

The maximum flood discharge for a single day is estimated as 1208 m^3/sec using this approach. However, evidence for a 40 m water rise in the cave passage of at least 40 m width has been reported [8]. Assuming a flow rate of at least 2 m/sec during such flood pulses gives an estimated maximum discharge of 3200 m^3/sec from the cave. Anecdotally, the villagers from the village (Ban Nongping) about 2 km downstream of the cave recounted water levels reaching within 15 cm of the floorboards of their elevated houses during the floods of October 2010, which were the largest in living memory. A hydrologic gauging station and weather station located somewhere near the cave resurgence would be a good starting point for increasing our knowledge of the hydrology of HNN.

There are few surface streams draining the HNN karst. In the central part of HNN the Houay Tia Lang (Figure 5) and Houay Kaan (Figure 6) flow out of the karst, on the surface in karst valleys, and into the Xe Bang Fai river a short distance upstream of the river cave. The local base-level control for the HNN karst appears to be the basement sandstone of the Boualapha Formation, which underlies the karst and floors the border poljes and valleys to the west of HNN.

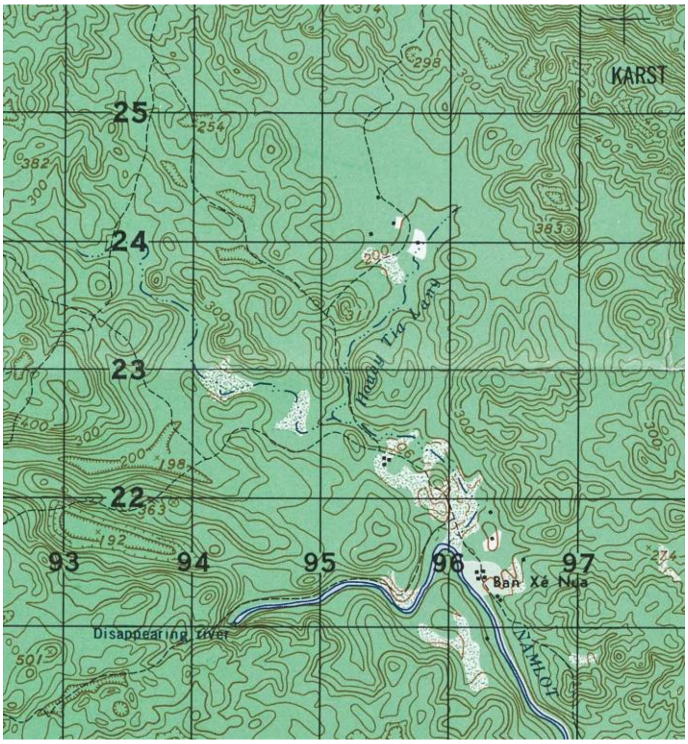

Figure 5. Map showing the Houay Tia Lang stream and the Xe Bang Fai river (1 km grid).

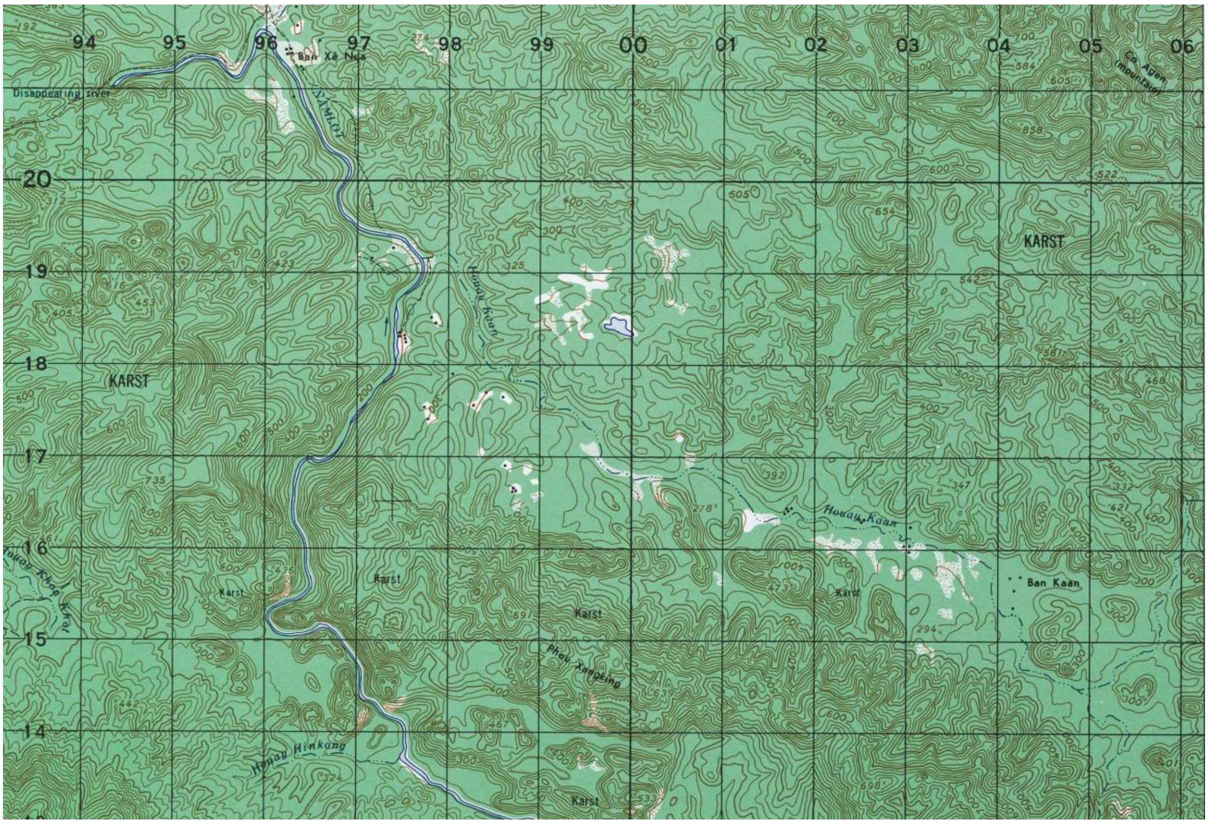

Figure 6. Map showing the Houay Kaan stream and the Xe Bang Fai river (1 km grid).

It is generally presumed that the underground drainage systems of the HNN karst flow into the Xe Bang Fai or Nam Ngo rivers. However, it is possible that some of the underground drainage of the HNN karst flows to the karst of PNKB in Vietnam, and vice-versa. There is anecdotal evidence of water from HNN flowing out of a karst spring in PNKB [12].

COMPARATIVE ANALYSIS OF HIN NAM NO AND PHONG NHA KE BANG

Feature	**Phong Nha Ke Bang**	**Hin Nam No**
Terrain	*Large continental plateau (dissected)*	Large continental plateau (dissected)
Lithology	Limestone, Dolomite (>75% of area)	Limestone, Dolomite (>90% of area)
Formation	Devonian, Carboniferous, Permian	Carboniferous, Permian
Texture	Hard, compact, pure	Hard, compact, pure
Stratigraphy	*Interbedding of shale and sandstone*, *Capping of schists and granite* Mesozoic clastic rocks deposited unconformably above the limestone (*formerly buried paleokarst*)	Not known to occur, Not known to occur Mesozoic clastic rocks deposited unconformably above the limestone (formerly buried paleokarst)
Geologic Structure	Truong Son anticlinorium extending NW-SE, reactivated during the Cenozoic to the present. Synclines more developed in PNKB.	Truong Son anticlinorium extending NW-SE, reactivated during the Cenozoic to the present.
Karst landscape evolution	Karst landscape evolution since early Mesozoic (paleokarst); with modern karst formation and rejuvenation, related to tectonic uplift and faulting in the Cenozoic, from the Miocene to the present. Non-karst landforms above the karst Residual/mature karst features, *At least one period of hydrothermal activity*	Karst landscape evolution since early Mesozoic (paleokarst); with modern karst formation and rejuvenation, related to tectonic uplift and faulting in the Cenozoic, from the Miocene (?) to the present. Non-karst landforms above the karst Residual/mature karst features. Possibly a more mature karst landscape than PNKB. Not known to occur
Karst landforms and features	*Dissected plateau* with polygonal cone karst, *Extensive closed or border depressions (polje)*, Planation surfaces at 7 levels Pinnacles not known to occur (?) *Some of the world's largest caves and underground rivers (Son Doong cave)* *Changes in routes of underground rivers,* *Cave passages at different levels (fossil),* *Giant speleothems (deposition and re-solution)*	Dissected plateau with polygonal cone karst, Extensive closed or border depressions (polje), Planation surfaces recognized at 3 levels Spectacular pinnacles a signature feature Some of the world's largest caves and underground rivers (Xe Bang Fai cave), Changes in routes of underground rivers, Cave passages at different levels (fossil), Giant speleothems (deposition)
Climate	Humid tropical coastal / monsoonal, 6 month dry season (January-June)	Humid tropical monsoonal, 7 month long, hot dry season (November-May)
Karst hydrology	Autogenic and allogenic recharge, Direction of rivers (surface and underground) is mainly SW-NE or S-N.	Autogenic and allogenic recharge, Direction of XBF river is SE-NW, then E-W through the cave and beyond.
Vegetation	Extensively forested (94%), with 84% (of total) primary forest. Mainly evergreen forest.	Extensively forested (83%), with 41% (of total) fairly sparse deciduous or xerophytic forest on limestone.

Hin Nam No (HNN) and Phong Nha Ke Bang (PNKB) are both part of a large (~3000 km^2), dissected karst plateau which comprises the eastern part of the Central Indochina Limestone karst region. Thus, there are many similarities, but some key differences between the two properties. These similarities and differences are outlined in the table above and discussed below. Note that features in *italics* are those that are recognized as being of Outstanding Universal Value under Criterion viii (Geoheritage) for PNKB by UNESCO World Heritage (WH).

LITHOLOGY AND STRATIGRAPHY

This karst plateau comprises greater than 75% of the area of PNKB and greater than 90% of the area of HNN. The carbonate rocks are of limestone, dolomitic limestone or dolomite lithology, and are hard, compact and pure. The karst of HNN is formed in the Carboniferous-Permian Khammouane Formation, whereas in PNKB the karst also contains a Devonian period limestone member, the Phong Nha Formation, which underlies the Carboniferous-Permian Bac Son Formation. The Bac Son Formation constitutes the main area of the limestone massifs of PNKB, however cave entrances such as Phong Nha Cave, Dark Cave, etc. occur in the Phong Nha Formation [8, 11].

The limestone in PNKB is said not to be continuous, but demonstrates *complex inter-bedding with shales and sandstones* (however, little information is provided about this phenomenon in the WH nomination dossiers). This complex inter-bedding is not known to occur in HNN, where the Khammouane limestone is massive and up to 1100 m thick. Furthermore, it is claimed that in PNKB there is *capping of the limestone with schists and apparent granites*, which have probably been thrust over the limestone, and are now eroded to a remnant outcrop (again, little information is provided about this phenomenon in the WH nomination dossiers). Capping of the limestone with schist and granites is not known to occur in HNN. This complex inter-bedding with shales and sandstones, and capping with schist and granites is said to have led to a *particularly distinctive topography* for PNKB. Further, it is said that *the location and form of the caves in PNKB suggests that they might owe much of their size and morphology to some as yet undetermined implications of the schists and granites which overlay the limestone*. If these features (inter-bedding and capping) are confirmed not to occur in HNN, then the morphology of the landforms and caves of HNN should differ from those of PNKB [8, 11]. These features need to be assessed by the Geoheritage/Karst WH expert (refer to study 3 in the action plan, next section).

There is evidence of *formerly buried and now uncovered paleokarst* in PNKB. Two Cretaceous sedimentary basins of the Mu Gia sandstone formation are recorded in the southeast and the west (near Mu Gia Pass) of PNKB. The Mu Gia sandstone was deposited unconformably on the (karstified) limestone massif. Uplift during the Paleogene caused intensive erosion and the Mu Gia sandstone was stripped off of the limestone, which by the Neogene became re-exposed and the modern period of karstification commenced. Aside from the unconformity, few or no paleokarst features have been documented in the PNKB WH nomination dossiers [11, 12]. The evidence for paleokarst in central Laos has been much better documented by Mouret [6]. However, few paleokarst features have been documented in HNN itself. A karst breccia paleo-cavity fill has been observed in one of the upper-level side passages of the Xe Bang Fai cave. More paleokarst features in HNN need to be identified and documented (refer to study 2 in the action plan).

GEOLOGIC STRUCTURE

The geological structure of PNKB and HNN is dominated by the Truong Son anticlinorium extending NW-SE. It was formed during the late Devonian to early Carboniferous, and reactivated during the Cenozoic to the present. The synclines are more developed in PNKB compared to HNN. In addition, faults are widely developed in PNKB, and play an important role in the formation and complexity of the geologic structure. In PNKB there are two main fault systems: one trending NW-SE, and a second trending NE-SW. These fault systems have and continue to play an important role in the formation and evolution of the karst. The fault systems in HNN have not been studied in any detail, but geologic maps of the area indicate primary faults trending NW-SE, and NE-SW trending secondary faults [8, 10, 11].

KARST LANDSCAPE EVOLUTION

Karst landscape evolution began in the early Mesozoic when the Carboniferous-Permian carbonates of PNKB and HNN were uplifted to subaerial positions, and a long karstification episode ensued. The karst was subsequently buried under thick layers of late Triassic, Jurassic and early Cretaceous sandstones and shales. A new uplift began in the Paleogene, leading to large scale erosion. As the limestone became progressively re-exposed karst evolution resumed in earnest. The modern karst evolution is thought to have commenced in the Miocene for PNKB. Tectonic uplift and faulting during the Cenozoic has influenced the formation and rejuvenation of the karst landscapes of PNKB and HNN [6, 11]. Despite a long period of landscape evolution, the effects of rejuvenation have resulted in the karst at PNKB now representing an early stage of landscape evolution (plateau with cone karst), even though it contains residual, mature karst features such as polje. This is largely the case for HNN also, but it has been suggested that the karst landscape of HNN is more mature than at PNKB [13].

The topographic relationship of sandstone elevated above the limestone karst is recognized as being an important feature controlling the karst landscape evolution in the Khammouane Limestone [7] This relationship between non-karst and karst landforms has also been recognized as an important feature of PNKB (but not as a feature of OUV), and a point of distinction from other karst sites such as Halong Bay, Dong Van Karst Plateau, and the South China Karst (?), where the karst is higher than the non-karst landforms [11].

Finally, in PNKB there has been *at least one period of hydrothermal activity in the evolution of the karst system.* However, no evidence is provided about this phenomenon in the WH nomination dossiers [11, 12]. A period of hydrothermal activity is not known to have occurred in HNN.

In general, the landscape evolution story has been little studied in HNN compared to in PNKB. This is a key deficiency that needs to be addressed for developing the justification of OUV for the geoheritage of HNN (refer to studies 1 and 3 in the action plan).

KARST LANDFORMS AND FEATURES

PNKB is part of a larger *dissected plateau* with polygonal cone karst that also encompasses the HNN karst. The characteristic landscape style of the HNN karst is that of a dissected plateau of karst massifs that are almost completely bordered by bare limestone walls or cliffs rising up to 500 m above intervening alluvial plains and flat-bottomed basins. In PNKB the fengcong karst landscape is not quite as dramatic, rising more gently above the river valleys, with less of the high fringing cliffs that so distinguish the Hin Nam No karst [11, 13].

Within or at the margins of the karst plateau (in both PNKB and HNN) are *extensive closed or border depressions* (flat floored valleys) with steep walls, known to karst specialists as *poljes*. Poljes are a ‘climax’ form, indicating well-developed karst. Karst towers occur around the edges of some poljes in HNN.

In PNKB, planation surfaces at seven elevations have been recognized, and associated with seven tectonic uplift cycles during the Cenozoic. The highest planation surface is at 1600-1400 m, found only on the Mesozoic sandstone and shale formations, and dated to the Oligocene. The planation surface at the top of the limestone is found at 1000-800 m in the west (crest of the plateau and PNKB-HNN boundary area) and 700-600 m in the east, and dated to the Miocene [11]. These two highest planation surfaces are also found in HNN. A Pliocene aged planation surface 600-400 m (west) or 300-200 m (east) is found in PNKB, but has not been recognized in HNN. Below 100 m, four more planation surfaces are found in PNKB, but do not occur in HNN. In HNN there is a planation surface at 220-170 m associated with the poljes and river valleys.

Sharp-edged and spectacular pinnacles up to 10 m high [8] are signature features which give Hin Nam No its name (i.e. spiky rocks in English). Such pinnacles do not seem to occur in PNKB, as they are not mentioned in the WH nomination dossiers [11, 12].

The karst of PNKB and HNN contain *some of the world’s largest diameter cave passages and large underground rivers*. In PNKB, Son Doong cave is possibly the world’s largest cave passage in terms of volume (diameter and continuity). In HNN, the Xe Bang Fai river flows underground through the karst for 6.4 km, creating one of the largest active river caves (by passage volume and water flow) in the world. In PNKB there is evidence of *major changes in the routes of underground rivers*. In the Xe Bang Fai cave system in HNN there is also evidence of major changes in the route of the underground river, both upstream of the current active river passage, and in the downstream section of the cave [1, 9, 11, 12].

In PNKB the caves demonstrate a discrete sequence of events, leaving behind *different levels of ancient abandoned (fossil) passages*. The numerous cave passages in the PNKB karst have been categorized into four discreet elevation levels that have been correlated with the aboveground terraces and planation surfaces, and thought to range in age from Pliocene to late Pleistocene. There are active stream caves up to the highest elevations, in addition to the fossil passages [11]. While there are cave passages at (at least two) different elevations in HNN, they have not been systematically studied to correlate them with the aboveground landscape surfaces or to determine their age.

The caves in PNKB contain *giant speleothem deposits, some of which have been partly re-dissolved*. The Xe Bang Fai cave also contains giant speleothem deposits including stalagmites, cave pearls, and gour pools, including a 61 m long gour basin considered to be the world’s largest single gour pool to have formed in a cave. However, evidence of re-solution of cave speleothems has not been documented in HNN [2, 9, 11].

The landforms and features of HNN need to be assessed by Geoheritage/Karst WH expert to determine which features represent or contribute to the OUV of the property (study 3).

CLIMATE

One of the key differences between PNKB and HNN is the climate on the two sides of the border. On the Vietnam side, the prevailing climate is generally moist throughout the year as a result of the influences of the South China Sea and the Truong Son Range, which forms an important divide between the PNKB and HNN portions of the karst plateau. The annual mean temperature is 24 C in PNKB and 26 C in HNN [5, 12].

PNKB receives an average of 2000-2500 mm annual rainfall, with annual rainfall of about 3000 mm in the area near the Vietnam-Laos border. The wet season is from July through December. The rainfall during this period accounts for 88% of the total annual rainfall. The dry season is from January until June, but despite the low rainfall during this period the average number of rain days still exceeds more than 10 days per month [12].

In comparison, HNN has a tropical, monsoonal climate with a distinct wet season and a long, hot, dry season. Annual rainfall in HNN is estimated to range from 1500-2200 mm. The wet season is from June through October [5]. The dry season (November-May) in HNN is longer and drier than in PNKB. These differences in climate have influenced the vegetation (see below) and possibly the geomorphology of the two properties.

KARST HYDROLOGY

In both PNKB and HNN, the karst hydrology is comprised of both autogenic and allogenic water sources. In PNKB there are five river systems in the karst/core zone which flow (surface and underground) mainly SW-NE or S-N into the Gianh river and then into the South China Sea, only 22 km east of the property [3, 12]. Thus, the distance between the top of the watersheds and the sea is quite short.

In HNN there are two river systems that drain the karst (Figure 2). The Nam Ngo is an autogenic river that drains the northern area of HNN and then flows into the Xe Bang Fai river to the west of the property. The Xe Bang Fai is an allogenic river whose headwaters are on non-karstic rocks about 40 km to the south of HNN. It flows from SE-NW along the western edge of the HNN karst before turning west to flow through the Xe Bang Fai cave. Upon exiting the cave and the karst of HNN it continues to flow west about 130 km to the Mekong river. There are few surface streams draining the karst area of HNN.

It is thought that there may be underground conduits between the two drainage areas within the deep interior of the karst plateau. There have been anecdotal reports about brown water and increased flows coming out at the Nuoc Mooc spring in PNKB at times when there was heavy rain in HNN but little or no rain in PNKB, this water presumably coming from the Lao side of the border [12]. It is worth noting that the catchment area for the water feeding the Nuoc Mooc spring is unknown [3]. Although there may be a hydrologic connection, at least during the height of the HNN wet season, the current evidence is unclear and largely anecdotal.

In PNKB a baseline sampling of water quality was conducted for 26 locations around the site, with samples analysed for a number of parameters, based on the standards for surface and underground water [3]. Information on water quality in HNN is lacking, but is needed to develop the protection and management, and monitoring requirements for the OUVs (refer to study 5 in the action plan).

VEGETATION

PNKB is estimated to be 94% forested with 84% of the total area being dense or mature forest. In contrast HNN is estimated to be 83% forested, with 41% of the total area being fairly sparse deciduous or xerophytic forest on limestone. Above 700 m elevation, the PNKB side of the plateau supports submontane and tropical moist evergreen forests on limestone karst. The forests in the east of HNN are the only example of tropical moist evergreen forest on limestone on the Lao PDR side of the plateau. [5, 11, 12].

CONCLUSIONS

This initial comparative analysis shows that HNN has many of the same geoheritage features as those recognized as being of OUV for PNKB. Many of these features for HNN are at least as good as, or add value to, the features of OUV for PNKB. Whether any of the similar OUV features are better in HNN could not be determined from this desk study and still needs to be assessed by the Geoheritage/Karst WH expert. The similarity of geoheritage features between HNN and PNKB is important for making the case for HNN as a transboundary extension to the PNKB World Heritage site.

The comparative analysis only identifies two features in HNN that differ or are not present in PNKB. One is the 'signature' karst pinnacles in HNN. The other is that the HNN karst landscape may be more mature that that of PNKB. Finally, the topographic relationship of non-karst landforms elevated above the limestone karst is recognized as being an important feature controlling the karst landscape evolution in both HNN and PNKB. Whether any of these features represent or contribute to OUV will need to be assessed by the Geoheritage /Karst WH expert.

On the other hand, there are several OUV features in PNKB that do not appear to be present in HNN. These include: *Interbedding of shale and sandstone, capping of schists and granite,* and *at least one period of hydrothermal activity,* which are said to have led to the *distinctive geomorphology of the landforms and caves* of PNKB. If these features are confirmed not to occur in HNN, then the morphology of the landforms and caves of HNN may be expected to differ from those of PNKB. Again, this will need to be assessed by the Geoheritage/Karst WH expert.

The comparative analysis also highlights the lack of knowledge about the stratigraphy, landform geomorphology, and landscape evolution of HNN (and PNKB as well). Scientific studies and expert assessments to fill these knowledge gaps are needed to develop the justification of OUV for the geoheritage of HNN. Recommendations on the specific studies and assessments needed are provided in the following section of this report. Additional knowledge and assessment of the stratigraphy will be provided by studies 2 and 3. Additional knowledge and assessment of the landform geomorphology will be provided by studies 2, 3 and 4. Additional knowledge and assessment of the landscape evolution will be provided by studies 1 and 3.

There is also a lack of knowledge about the hydrology and water quality, of the Xe Bang Fai river especially, which is needed to develop the protection and management, and monitoring requirements for the OUVs. Baseline measurements, additional knowledge and assessment of the hydrology and water quality will be provided by study 5.

ACTION PLAN FOR GEOHERITAGE ASPECTS OF THE WORLD HERITAGE NOMINATION

The action plan for geoheritage aspects consists of three components: studies to fill knowledge gaps, a review of recommendations in the 'Readiness Assessment' report, and a review of the nomination roadmap in the same report.

Studies for 2017-2018 to fill gaps in knowledge about the HNN geoheritage

1. *Landscape Evolution, Hydrology, and Climate History of Xe Bang Fai Cave and Nam Ock Cave*. This study involves collecting and dating of stalagmites and flowstone to determine a minimum age for events in the evolution of the caves and the greater karst landscape, and isotopic analysis to determine past climate in the HNN region. International researchers are Drs Kathleen Johnson and Michael Griffiths. Proposed field mission from 6-18 January, 2018. A short proposal for this study has already been submitted to the HNN Project.

2. *Exploration and Documentation of Caves in Hin Nam No*. The objective of this study is to gather further information on the cave resources of HNN, with a focus on the hydrology and biology of the caves, and documenting any evidence of paleokarst. International speleologists will be team members of the Explo-Laos group based in France. Proposed field mission likely to be late February-early March 2018. A proposal with dates, team members and objectives is forthcoming.

3. *Geoheritage OUVs and Global Comparative Analysis for HNN*. This study will involve a field visit to HNN to describe the HNN karst, its geomorphology and evolution, and to identify its case for OUV (justification for criterion viii). Also to develop a global comparative analysis (after the field visit). The International Geoheritage/Karst WH expert is Dr Paul Williams. His visit will be conducted as an official IUCN consultancy to the Government of Lao PDR state party. Proposed field mission to be about 8-10 days, sometime in February or March, 2018 (to be scheduled).

4. *Laser Scanning the Xe Bang Fai Cave*. This study will laser scan the active river passage of the Xe Bang Fai cave. This will provide a very accurate 3D representation of the cave, which will allow the size of this passage to be determined and ranked relative to other large caves of the world. The International Expert team will be led by Roo Walters. This study was already proposed and approved for February 2017, but had to be delayed. The field mission would be about 12 days in mid-March to early April, 2018 (to be scheduled).

5. *Hydrology and Water Quality of the Xe Bang Fai River, and Weather in HNN*. This study would provide some baseline an ongoing monitoring data on the HNN site for the WH nomination dossier. Water quality in particular is an important component of site integrity and management in a karst WH site. Samples for water quality analysis should be taken at a number of locations around HNN, and during the different seasons of the year. Somewhere inside or near the downstream entrance of the Xe Bang Fai cave (Ban Nongping area) would be the logical place to set up a hydro-met station for measuring river stage and discharge rate, rainfall, temperature, etc. This study probably could

(should?) be conducted by the Department of Meteorology and Hydrology of the Government of Lao PDR. International expertise can be identified if needed.

Review of recommendations in the 'Readiness Assessment' report related to geoheritage aspects. (numbering below reflects the recommendation number in the report).

3. *Address gaps in knowledge of geoheritage values for HNN*. Priority: Medium. Refer to Studies section above on specialist studies by experts to fill gaps in knowledge about the HNN geoheritage.

5. *Review IUCN methods for comparative analysis and review recent tropical karst WH nominations*. Priority: Medium. The comparative analyses and statements of OUV for PNKB, Trang An, and South China Karst WH sites were reviewed as part of developing the comparative analysis between PNKB and HNN in this report.

6. *Commission a global comparative analysis for HNN*. Priority: Medium. This has been discussed with Paul Williams in person and by email, and he has agreed to visit HNN in early 2018 and write a global comparative analysis (refer to Studies section above).

7. *Compare HNN's geoheritage values with PNKB in terms of complementarity, distinctiveness and degree of connectivity*. Priority: Medium. This has largely been done in the comparative analysis of HNN with PNKB in this report. The draft comparative analysis was reviewed by Paul Williams and revised accordingly. Further input from Paul Williams will be made after his field visit to HNN in early 2018.

9. *Undertake OUV attribute mapping for HNN geoheritage*. Priority: Medium. This work can be initiated by the geoheritage consultant with the HNN Project team, based on the comparative analysis in this report. It can then be further developed after Paul Williams' visit to HNN and identification / confirmation of geoheritage features of OUV.

10. *Review and adjust the boundaries of HNN to include all attributes of OUV (and their integrity)*. Priority: Medium. This task is to be done by the HNN Project and GoL with input by the geoheritage consultant, after OUV features have been identified and mapped (recommendations 7 and 9, above).

17. *Review the cave and karst protection and management regime*. Priority: High. This task to be done by the geoheritage consultant working with the HNN Project team.

18. *Prepare a Xe Bang Fai cave management and development plan*. Priority: High. This task to be done by the geoheritage consultant in consultation with the HNN Project.

20. *Revise the HNN co-management plan to prioritize the protection of geoheritage OUV*. Priority: Medium. This task to be done by the HNN Project and GoL with input by the geoheritage consultant.

28. *Analyze threats to HNN and possible impacts on OUV*. Priority: Medium. This task to be done by the HNN Project and GoL with input by the geoheritage consultant.

32. *Reconcile HNN development with provincial and district development plans for tourism*. Priority: High. This task to be done by HNN Project and GoL with input by the geoheritage consultant.

37. *Determine essential seasonal environmental flows of the XBF river in HNN and provide assurances as to how this watershed will be protected (and managed) to maintain the OUVs and their integrity*. Priority: Medium. Determining the essential environmental flows can take advantage of the hydrology information provided in the Review section of this report and from the study proposed above on the hydrology of the Xe Bang Fai river. Providing assurances on the protection and management of the watershed is to be done by the HNN Project and GoL with input by the geoheritage consultant and the meteorology and hydrology experts.

48. *Seek upstream advice from WHC / IUCN in advancing the nomination*. Priority: High. Paul Williams, the geoheritage/karst WH expert, is to be contracted to come as an IUCN consultant to the Lao PDR state party (refer to the Studies section above).

Nomination Roadmap related to geoheritage aspects, assuming a standard WH nomination structure (numbering below refers to the roadmap step number in the 'Readiness Assessment' report).

5. *Upstream support from WHC / IUCN secured*. Refer to recommendation 48 (above).

8. *Geoheritage values inventoried and mapped.* Refer to recommendation 9.

9. *State of conservation of geoheritage values confirmed*. Refer to recommendations 10, 17, 18, 20 and 28.

10. *Description of the HNN property complete*. Information on geoheritage aspects of the property to be provided by the geoheritage consultant.

11. *Global comparative analysis complete*. Refer to study 3 (above).

12. *Justification for inscription complete.* The justification for inscription addresses OUV, its integrity, and its protection and management. Information concerning the geoheritage aspects of the justification to be provided by studies 1-4, and many of the recommendations above. The geoheritage aspects to be drafted by Paul Williams and the geoheritage consultant, in collaboration with the HNN Project and GoL.

13. *Draft statement of OUV complete*. The draft statement of OUV is a concise version (limited to two A4 pages) of the Justification for inscription. The geoheritage aspects to be drafted by the geoheritage consultant, in collaboration with the HNN Project and GoL.

17. *Tourism and Xe Bang Fai cave management planning complete*. Refer to recommendations 17, 18, 20 and 32.

19. *Nomination dossier finalized (assembled and reviewed)*. The nomination dossier to be reviewed for all aspects related to geoheritage by the geoheritage consultant and the WH expert on Geoheritage (Dr Paul Williams). Consideration should be given to having the nomination dossier reviewed also by a wider WH reference group.

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